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From L' Illustration

Ruins of the Arras Cathedral

A MONUMENT TO THE HUN—**[See page 295]**

Problems of Atomic Structure—I*

Differences Characteristic of Different Elements, and Mechanism of the Molecule

By Sir J. J. Thomson

FOLLOWING what is now a long-established precedent, Sir J. J. Thomson, O.M., P.R.S., has given at the Royal Institution this session a course of lectures setting forth in plain language certain of the problems now confronting physicists, the means and methods by which they are being attacked and the progress made towards satisfactory solutions.

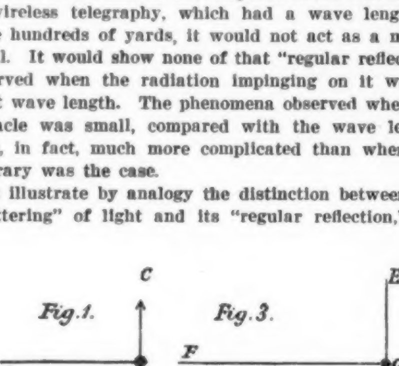
In his opening lecture Professor Thomson said that he proposed to consider in this series what light had been thrown, by investigations carried out during the past few years, on the structure of the atoms, on the differences in atomic structure characteristic of different elements, and on the mechanism by which one atom was united to another, to form a molecule either of an element or of a chemical compound. We would, he believed, start from firm ground in supposing that one of the things that went to build up the atom was the electron. The electron was a small particle having a mass which was but a minute fraction of that of the hydrogen atom, and it carried an invariable charge of negative electricity. He had often shown in that room how these electrons might be liberated by different agencies. They were, for example, given off in streams from incandescent metals. Again, if ultra-violet light or Röntgen rays acted on different substances these were also caused to emit streams of these electrified particles, the nature of which did not depend in any way on the character of the agent used or on the material from which the particles were emitted. We were thus on quite firm ground in assuming that these electrons formed part and probably a very essential part of the structure of each atom. It was natural to try and see whether we could not go further. Undoubtedly each atom possessed electrons, but how many? Could we contrive to find out in any way the number in any particular atom? How did this number vary when we passed from hydrogen to one of the heavy atoms such as gold or platinum?

It was mainly to this problem of finding the number of electrons in an atom that he proposed to devote attention that afternoon. This problem was not one that could be solved by direct frontal attack. We might, amongst the *debris* left in a vacuum tube through which an electric discharge was passed, try to pick out some atoms from which the electrons they possessed had been torn out, and it was true that in such tubes atoms were found which had lost electrons. Thus in positive ray analysis large numbers of atoms were found, which had lost one or two electrons. The loss was greatest in the case of mercury, some positive rays of which showed a loss of seven electrons.

There was, however, no reason to believe that in positive ray analysis we exhausted the store of electrons in the atoms, taking from them all that they possessed. It was therefore necessary to try and devise some other method, which would enable us to form an accurate estimate of the total number of electrons in an atom. The simplest method, and the one exposed to the fewest ambiguities, depended on measuring the effect of the little wavelets, which would be started by an electron if placed in the path of any electric wave. An electric wave consisted of electric forces propagated outwards and changing in their direction with a rapidity which depended on the character of the wave. Suppose an electron were placed in the path of a wave of this kind. Let the force in the wave be represented by the vertical line BC in Fig. 1, and the direction of propagation by the line AB. Then an electron placed at B would be moved up in the direction BC, and as the direction of this force changed so would also the motion of the electron, which would thus be waggled up and down. By this motion, it would itself become a generator of little electric wavelets, as would all the other electrons encountered by the wave. Each of these would, in fact, start little waves "on its own." If then we could determine the number of the little wavelets started when an electric wave fell on the electrons of an atom, this number would be equal to the number of electrons in that atom.

It was this method he proposed to discuss that afternoon; and he would start by showing what happened when a train of waves encountered an obstacle, and would demonstrate the difference between the reflection of waves by large obstacles and by small ones. When light fell on a mirror it went off again in a perfectly definite direction. That it did so was due to the fact that the mirror was large in all its dimensions when compared with the wave length of ordinary light. If, however, such a mirror were exposed to the waves used in wireless telegraphy, which had a wave length of some hundreds of yards, it would not act as a mirror at all. It would show none of that "regular reflection" observed when the radiation impinging on it was of short wave length. The phenomena observed when the obstacle was small, compared with the wave length, were, in fact, much more complicated than when the contrary was the case.

To illustrate by analogy the distinction between the "scattering" of light and its "regular reflection," the



lecturer started a series of wavelets in a trough of water, the surface of which was strongly lighted and reflected with considerable magnification on to a screen. Placing a long bar of wood in the path of these wavelets, it was shown that the wavelets advanced up to the obstacle in regular lines and were reflected in the same way. Replacing this bar by a small float, the effect was quite different in character. The main wave proceeded on past the obstacle, whilst the latter on being thus disturbed set up little wavelets of its own which spread out radially in all directions, the crests and hollows forming complete circles round the small

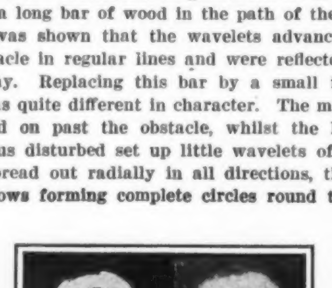


Fig. 2

obstacle as centre. In the corresponding case in optics the light was said to be "scattered" when reflected from objects which were not large in comparison with the wave length. The properties of the little wavelets then set up had been first studied by Lord Rayleigh in a paper "On the Scattering of Light by Small Particles." Lord Rayleigh had shown that the light scattered by such particles would be the more intense the shorter the wave length, so that blue light would be scattered more than red. Hence if white light were allowed to fall on small particles the scattered light would be more blue than red, and Rayleigh suggested that the blue of the sky was accordingly to be attributed to this scattering of light by numerous small particles of dust suspended in the air. He even suggested that the light scattered by the very molecules of the air might be sufficiently intense to account for the blue of the sky.

Professor Strutt (Lord Rayleigh's son) had quite recently in some most interesting experiments confirmed the conclusion that the molecules of the air were capable of scattering light. He had actually photographed the light reflected from the molecules of air from which all dust had been completely excluded. A reproduction of some of Professor Strutt's photographs is given in Fig. 2. That in the left hand top corner of the figure showed, the lecturer said, the path of a beam of light across a bulb containing perfectly dust-free air. The circle showed light reflected from the walls of the bulb; it was not scattered light, but the beam could also be clearly seen crossing the tube, so that enough light to affect a photographic plate was scattered by the air molecules. The view on the left was, he said, taken through a screen transparent to ultra-violet light. On the top right-hand corner of the figure was shown another photograph taken this time through a yellow screen. In this case, although the outer ring due to light reflected from the bulb walls was as marked as ever, practically all trace of light scattered from the air molecules had disappeared. The two views provided a good illustration of the fact that the intensity of the light scattered by small particles increased very rapidly as the wave length diminished. The scattering of the ultra violet was very strong, whilst that of the yellow light was hardly appreciable.

The same thing was shown, the lecturer continued, by the two spectra reproduced in the middle of the figure. Here the upper was the spectrum of the scattered light and the lower that of the incident light, which was furnished by a mercury lamp, of which the photograph represented the normal spectrum. Strong lines in the yellow of the incident light were invisible in the spectrum of the scattered light, and the latter showed lines in the ultra-violet which were extremely faint in the lower spectrum. The two spectra were obtained with very different exposures, so that they afforded data for comparing merely the relative strength of the lines in the two cases. They showed, however, very clearly that the "centre of gravity" of the "scattered" spectrum had been shifted a long way towards the ultra-violet.

In the lower left-hand corner of the figure were two views taken through a Nicol prism. With this prism in one position the upper view was obtained, whilst the view below was taken with the nicol turned through a right angle. In this case the scattered light was completely extinguished, which proved that it was completely polarised. This was in fact a distinguishing characteristic of scattered light. If there were any question as to whether light was scattered or came from some other source, we might be sure that if it was not polarised it was not due to scattering.

The lecturer illustrated this by showing that the light scattered by the small particles produced by pouring into water a solution of mastic in alcohol was almost completely polarised and, he repeated Tyndall's experiment in which the particles scattering the light were produced by the action of the light itself on the vapour of amyl nitrite. He showed also that light was scattered when a beam of it was passed through iodine vapor. In the experiment with mastic, he said that the particles concerned, though small, compared with the wave length of the light, were large as compared with molecules, whilst in the experiment with iodine vapor, the phenomena was more complex, since the effect observed was not due to simple straightforward reflection by the molecules.

He had brought forward these examples of the behavior of scattered light, because the same principles could be applied when particles still smaller than the molecules, viz., the electrons were concerned. Before it was permissible to assume that effects observed were to be explained by scattered reflection, certain tests must be applied. The light scattered by molecules was proved to be polarised. Was the Röntgen radiation scattered from electrons also polarised? That this was so had been proved by Barkla, who had brought forward conclusive evidence showing that this was the case with the Röntgen rays. These rays were now known to be electrical waves with a wave length much smaller than that of ordinary light, and of which the electric force accordingly changed its direction much more rapidly. Electric waves were generated by the motion up and down of an electrified body. The energy of the wave was propagated in all directions but one, no flow of energy being detectable in a direction along the line of motion of the vibrating particle. The maximum effect was observed in a direction at right angles to this line of motion, but as stated no waves could be detected as

*Reported in *Engineering*.

coming to the observer along the axis of the motion. Thus if in Fig. 3 GE represented the line of motion of an electron set vibrating by the electric wave reaching it along the direction FG, a wave detector placed at H in line with GE would record nothing. Whilst if it were placed along a line perpendicular to the plane of the paper a maximum effect would be attained. Hence if it were proved that Röntgen ray effects showed a maximum in one direction, and were zero in another direction at right angles to this, it would constitute strong evidence that the phenomenon corresponded to a complete polarisation of the electric force. In actual fact, matters were not so simple. We had to deal not with one electron, but with many, vibrating in all directions normal to the path of the impinging wave. Hence whilst no effect due to an electron vibrating along the line EG would be detectable at H, there would be an effect here due to some other electron vibrating at right angles to the plane of the paper. The result was that the effect observed was constant when the detector was placed anywhere in a plane drawn through EG and perpendicular to FG. If, however, the detector were placed out in front of the obstacle it would then point along a line at right angles to the motion of all the vibrating electrons and the effect would be twice as great as if at H. A very stringent test could thus be made as to the polarisation of the wavelets generated by the electrons in an atom. Barkla had shown that the condition in question was satisfied with great accuracy, thus providing very good evidence in favor of the view that when we examined the effect of Röntgen rays on substances we had to do with wavelets started by the motion of electrons within the atoms.

The problem then arose as to how could we calculate from measurements made on these wavelets the number of electrons in the atom, or what was the same thing, the number of wavelets started. The solution of this problem involved an application of one of the most fundamental principles in physics and very generally applicable. If but one centre were in operation the problem was easy, but each electron was pretty sure to be one of a crowd. How would the disturbances from these separate centres coalesce? Would they simply add up, or was their resultant expressed by some more complicated law?

It turned out that according to the conditions either alternative might hold. If two electrons lay close together along the line of propagation of the incident wave, their resultant effect would depend upon the wave length. If the distance between the two was small compared with this wave length both electrons would be set vibrating in phase, and the amplitude of the wavelets produced would be the sum of the individual amplitudes and the energy involved would be proportional to the square of this resultant amplitude, or four times as much as if a single electron only were concerned. In such a case as this, therefore, the energies were not simply additive, but the resultant value increased as the square of the number of electrons concerned.

If, on the other hand, the two electrons were far apart, the phases of their vibrations would no longer be identical, and the resultant amplitude of the wavelets generated would be, not the arithmetical sum of the individual amplitudes, but their vector sum. Thus in Fig. 4 the amplitude of each of a number of component wavelets was represented by the length of a line and the phase by the angle this line made with the horizontal axis. The resultant amplitude was then represented by the distance OP.

The phase of any component was a mere matter of chance. If all happened to have the same phase the resultant amplitude would be the simple sum of all the component amplitudes, but if the phase of each was a matter of chance the resultant amplitude might have any value less than the arithmetical sum. Lord Rayleigh had discussed the matter in a paper entitled "The Resultant of a Large Number of Uniform Vibrations of Arbitrary Phase." No objection could be taken to this title either on the score of accuracy or adequacy, but in essentials the problem was an older one, long known by a more disreputable name, viz., the "Drunkard's Walk." Suppose, for example, that at every 100 yards a pedestrian fell down, and on getting up restarted in a new and arbitrary direction. The problem was to find the distance he would have got from his starting point after a large number of attempts. Actually different men would get different distances, but if the experiment were made it would be found that with, say, 10,000 men, the results collected about a certain average value equal to the length of each journey multiplied by the square root of the number of the attempts. Were each journey one yard in length, and were 10,000 such journeys made, the average distance from the origin at which the men finished up would be $1 \times \sqrt{10{,}000}$ or 100 yards only. This result might serve to illustrate the difference between an expenditure of energy inspired by intelligence and "muddling through." In one case the result was proportional to the number of steps taken and on the other merely to the square root of this number.

[TO BE CONTINUED]

Appetites and Aversions as Constituents of Instincts*

By Wallace Craig, University of Maine, Orono

THE overt behavior of adult animals occurs largely in chains and cycles, and it has been held[1] that these are merely chain reflexes. Many years of study of the behavior of animals—studies especially of the Blond Ring-Dove (*Turtur risorius*) and other pigeons —have convinced me that, though innate chain reflexes constitute a considerable part of the instinctive equipment of doves, few or none of their instincts are mere chain reflexes. On the contrary, each instinct involves an element of appetite, or of aversion, or both.

An *appetite*, so far as externally observable, is a state of agitation which continues so long as a certain stimulus, the appeted stimulus, is absent. When the appeted stimulus is at length received it releases a consummatory reaction, after which the appetitive behavior ceases and is succeeded by a state of relative rest, a state of satisfaction. The appetitive behavior serves to bring about the appeted situation by trial and error. The appetitive state includes a certain *readiness* to act. When most fully predetermined this has the form of a chain reflex. But in the case of many supposedly innate chain reflexes, the reactions of the beginning or middle part of the series are not innate, or not completely innate, but must be learned by trial. The end action of the series, the consummatory action, is always innate. One evidence of this is the fact that in the first manifestation (also, in some cases, in later performances) of many instincts, the animal begins with an *incipient consummatory action*, although the appeted stimulus, which is the adequate stimulus of the consummatory reaction, has not yet been received. Thus the young dove when learning to drink makes drinking movements while searching for the water; and when its instinct to fly has ripened, it may make feints of flying, flapping its wings vigorously, and even aiming at an objective point, before it has dared to launch into the air. There are all *gradations* between a true reflex and a mere readiness to act, mere facilitation. In many cases the bird needs to *learn* to obtain the adequate stimulus for a complete consummatory reaction, and thus to satisfy its own appetites.

An *aversion* resembles an appetite in that it is a state of the organism characterized by agitation and persistency with varied effort; it differs from an appetite in that it continues so long as a certain stimulus, referred to as the disturbing stimulus, is *present*, but ceases, being replaced by a state of relative rest, when that stimulus has ceased to act on the sense organs. An aversion is sometimes accompanied by an innately determined reaction adapted to getting rid of the disturbing stimulus, or by two *alternative* reactions which are tried and interchanged repeatedly until the disturbing stimulus is got rid of. An example of aversion is the so-called jealousy of the male dove, which is manifested especially in the early days of the brood cycle. At this time the male has an aversion to seeing his mate in proximity to any other dove. The sight of another dove near his mate is an "original annoyer."[2] If he sees another dove near his mate, he may follow either or both of two courses of action; namely, (*a*) attacking the intruder, with real pugnacity; (*b*) driving his mate, gently, not pugnaciously, away from the intruder. The instinctive aversion impels the dove to truly intelligent efforts to get rid of the disturbing situation.

Instinctive activity runs in *cycles*. The type cycle, as it were a composite photograph representing all such cycles, would show four phases as follows.

Phase I. Absence of a certain stimulus. Physiological state of appetite for that stimulus. Restlessness, varied movements, effort, search. Incipient consummatory action.

Phase II. Reception of the appeted stimulus. Consummatory reaction in response to that stimulus. State of satisfaction. No restlessness nor search.

Phase III. Surfeit of the said stimulus, which has now become a disturbing stimulus. State of aversion. Restlessness, trial, effort, directed toward getting rid of the stimulus.

Phase IV. Freedom from the said stimulus. Physiological state of rest. Inactivity of the tendencies which were active in Phases I, II, III.

Some forms of behavior show all four phases clearly. In other cases one or other of the phases is not clearly present. When the bird shows appetitive behavior but fails to obtain the appeted stimulus, the appetite sometimes disappears, due to fatigue or to drainage of energy into other channels. But some instinctive appetites are so persistent that if they do not attain the normal appeted stimulus they make connection with some abnormal stimulus; to this the consummatory reaction takes place, the tension of the appetite is relieved, its energy discharged, and the organism shows satisfaction. This is "compensation" in the sense in which that word is used in psychiatry. The cycles and phases of cycles are multiplied and overlapped in very complex ways. Smaller cycles are superposed upon larger ones. The time occupied by each varies greatly, from cycles measured in seconds to those that occupy a year or even longer.

The successive phases are not sharply separated. Thus, from the last phase of one cycle in a series to the first phase of the succeeding cycle, there is often a gradual rise of appetite; active search for satisfaction does not commence until a certain intensity of appetite is attained. This is what is known in pedagogical literature as "warming up." This gradual rise of the energy of appetite is followed (Phases II-III, or II-IV) by its sudden or gradual discharge. The rise and discharge are named by Ellis,[3] in the case of the sex instinct, "tumescence" and "detumescence." They are important phases in the psychology of art, in which sphere they are named by Hirn[4] "enhancement" and "relief." The discharge (Phase II) is also exemplified in "catharsis" in art and in psychiatry.

All human behavior runs in cycles which are of the same fundamental character as the cycles of avian behavior. These appear in consciousness as cycles of attention, of feeling, and of valuation. This description is true not only of our behavior toward objects specifically sought by instinct, such as food, mate and young, but also of our behavior toward the objects of our highest and most sophisticated impulses, such, for example, as a symphony concert. The entire behavior of the human being is, like that of the bird, a vast system of cycles and epicycles, the longest cycle extending through life, the shortest being measured in seconds, each cycle involving the rise and the termination of an appetite. This view helps us to understand the laws of attention; for example, the law that attention cannot be held continuously upon a faint, simple stimulus. For as soon as such a stimulus is brought to maximum clearness, which constitutes the consummatory situation, the appetite for it is quickly discharged and its cycle comes to an end. This familiar fact illustrates the general truth that we, like the birds, have but a very limited power of altering the ebb and flow of our behavior cycles. Cyclical recurrence does not prove that human behavior consists of mere chain reflexes, neither does it prove that the instinctive behavior of birds consists of mere chain reflexes.

Doctor Raymond Pearl read a preliminary draft of this paper and suggested important improvements, for which I express my thanks.

The article of which this is an abstract will appear in the *Biological Bulletin*.

*Proceedings of the National Academy of Sciences.

[1]Herrick, C. J., *Introduction to Neurology*, 1915, (61).

[2]Thorndike, E. L., *The Original Nature of Man*.

[3]Ellis, H., *Studies in the Psychology of Sex. III. Analysis of the Sexual Impulse*.

[4]Hirn, Y., *The Origins of Art*.

The "Lafayette"

THE delicious small food fish, *Leiostomus xanthurus*, called "lafayette" near New York City, and which in occasional years like the present invades the harbors and rivers in such numbers that thousands of metropolis dwellers obtain pleasure in angling for it, belongs to the drum or weakfish family. Members of this family frequent sandy shores, being especially plentiful southward, and almost without exception are good food fishes. They make grunting or croaking sounds, from which characteristic several have received their common names. Lying at anchor on a quiet evening in some southern bay one at times hears the "wop," "wop" of the big sea drum.

—*The Am. Museum Journal.*

The Turtles of the West Indies

The Possibilities of Breeding Turtles in the Bahama Islands

By Theodoor de Booy

The more commonly-found sea-turtles of the West India waters are the three following kinds: the Green Turtle (*Chelonia mydas*), the Hawksbill Turtle also known as the Tortoise-shell Turtle (*Chelonia imbricata*) and the Loggerhead Turtle (*Caretta caretta*). In addition to these, Kemp's Turtle (*Colpochelys kempi*) and the Leatherback Turtle (*Dermochelys coriacea*) are also found, although not in such large quantities.

The catching of the two first-named turtles provides a not inconsiderable means of livelihood for the natives of the West India islands. It is from the over-lapping backplates of the Hawksbill Turtle that the tortoise-shell of commerce is procured. These imbricated plates consist of a horny substance, brown in color, marbled with yellow, and command high prices. They are used in inlay-work and for the making of various ornamental articles such as combs, pins, etc. The substance of which the plates consist can be molded and welded when hot and in consequence lends itself readily to manufacturing processes. The lower plates of this turtle are valueless, as is the meat. The animal being wholly carnivorous, the meat is generally not considered fit for consumption, although claims to the contrary have occasionally been brought forward. This turtle rarely exceeds two feet in size, weighing perhaps as much as 150 pounds; it derives its name from the resemblance between its bill to that of a hawk.

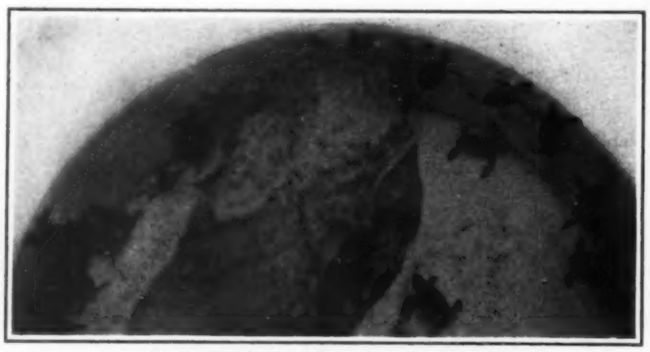
The Green Turtle on the other hand has a greenish or olive-colored shell which is absolutely valueless, and this animal is only esteemed for the delicacy of its flesh. It is generally considered to be herbivorous, living off the so-called sea-lettuce (*Ulva* grass) and a scheuchzeriaceous grass (*Thalassia testudinum*) found throughout Antillean waters, although it has been known to eat fish when kept imprisoned in small crawls in which no grass was found. The animal is said to grow to a weight of 400 pounds, but the size sought after by dealers and preferred by epicures does not exceed 100 pounds and is preferably less than this. Many of the West Indian governments, in order to prevent the extermination of these animals, have made the catching of green turtles below a certain size (generally 25 pounds) illegal and forbid the catching during the breeding and laying seasons. These rules also apply to the hawksbill turtles. Kemp's Turtle has a close outward resemblance to the Green Turtle and it is more than likely that a large percentage of edible turtles shipped to northern markets are of this variety, the flesh of the former tasting so much like that of the esteemed Green Turtle that it is doubtful if the average connoisseur would detect the difference. The Green Turtle derives its name from the fatty covering, green in color, which is found between the flesh and the plates.

The Loggerhead Turtle, sometimes named the Snapper Turtle, is absolutely valueless and, owing to its ferocity, somewhat dreaded by the turtlers of the West Indies. It is named Snapper, as it snaps at everything in sight and its beak is said to be so strong that it can crush the large conch-shell of the West Indies between its jaws in order to extract the conch. This turtle is carnivorous and its meat so oily that it cannot be eaten. In fact, it has sometimes been claimed that its flesh is poisonous, but this claim is erroneous as many instances are known where West Indian natives have been, from necessity, forced to eat the meat and have suffered no ill effects. The only use to which a Loggerhead Turtle is ever put is to make its upper shield serve

Turtle pond at Inagua, Bahamas

as a basin and stories are told where it has served as a canoe for small boys. This latter story seems credible when one reads accounts of this particular kind of turtle reaching a size of over 1000 pounds.

As the third species therefore has no commercial value and the catching of these at times is more an accident than anything else, we shall confine our attention to the two first-named turtles. Both are generally caught in the sea itself, although tales are told of fishermen surprising the turtles when they come ashore



Newly hatched turtle swimming in a tub

to lay their eggs in the sea-sand. When a turtle is surprised in this manner, it is frequently possible to turn it on its back, using a stick as a lever, before it has a chance to hurry to the water. Once on its back, the turtle is helpless. This method, however, is rather rare and the means in general use of catching the animals is to detect a turtle in the water and to drop a weighted, conical-shaped net over it. The turtle becomes entangled in this net and is easily captured. Occasionally, in the case of a small-sized animal, the natives will dive and get hold of the turtle from the top, placing their hands between the two front flappers in order to prevent themselves from getting injured, and capture it by these means.

The female turtle comes ashore at certain times of the year to lay her eggs, which she deposits in a shallow cavity dug in the sand with her hind flappers. The great naturalist, Audubon, who observed the habits of the turtles on the Florida coast, describes the habits of the female turtle in the laying season as follows:

"On first nearing the shore, and mostly on fine moonlight evenings, the turtle raises her head above the water, still being distant thirty or forty yards from the beach, looks around her, and attentively examines the objects on shore. Should she observe nothing likely to disturb her intended operations, she emits a loud, hissing sound, by which such of her many enemies as are unaccustomed to it are startled, and so are apt to remove to another place, although unseen by her. Should she hear any noise or perceive any indications of danger, she instantly sinks, and goes off to a considerable distance; but should everything be quiet, she advances slowly toward the beach, crawls over it, her head raised to the full stretch of her neck, and when she has reached a place fitted for her purpose, she gazes all around in silence. "Finding 'all well,' she proceeds to form a hole in the sand, which she effects by removing it from under her body with her hind flappers, scooping it out with so much dexterity that the sides seldom if ever fall. The sand is raised alternately with each flapper, as with a large ladle, until it has accumulated behind her, when, supporting herself with her head and forepart on the ground fronting her body, she, with a spring from each flapper, sends the sand around her, scattering it to a distance of several feet. In this manner the hole is dug to a depth of eighteen inches or sometimes more than two feet. This labor I have seen performed in the short period of nine minutes. The eggs are then dropped one by one, and disposed in regular layers to the number of one hundred and fifty, or sometimes nearly two hundred. The whole time spent in this part of the operation may be about twenty minutes. She now scrapes the loose sand back over the eggs, and so levels and smooths the surface that few persons on seeing the spot could imagine that anything had been done to it. This accomplished to her mind, she retreats to the water with all possible dispatch, leaving the hatching of the eggs to the heat of the sand.

"Each turtle has generally three layings in the season, at intervals of two or three weeks. The eggs are perfectly round, varying from two to three inches in diameter. The external membrane is flexible, very white, and contains a considerable quantity of calcareous matter."

Not only does the female turtle take precautionary measures in order to scare enemies away before landing and laying her eggs, but the West Indian natives also claim that she is in the habit of disturbing the sand in two or three different places, *after* smoothing the place in which her nest of eggs is actually found. There is every reason to credit this report, demonstrating how by these means, the animal lessens the chances of her eggs being dug up by such creatures of prey as crabs, foxes and birds. To the natives, the newly-laid turtle eggs are rare delicacies and eagerly sought after. Legislation in many of the West Indian countries prohibits the collecting of these eggs in order to prevent the extermination of turtles, but it must be said that these laws are somewhat ineffective on the sparsely inhabited islands frequented by the turtlers.

The eggs are hatched by the heat of the sand and after about seven weeks, the young turtles break through their shell and dig themselves to the surface. Turtlers state that the newly-hatched animals have an uncanny instinct of the direction in which nearest sea water is found and that even when the eggs have been taken inland and hatched several miles from the sea, the little turtle will point its nose in a direct line towards the sea and begin to make his way toward it. This belief is common throughout the West Indies and it is quite possible that it is founded upon fact. After emerging from its shell the future fate of the young turtle is precarious. The chances are that some large bird will swoop down upon it and swallow it as a dainty morsel before it reaches the water. Or should it reach the water safely, all sorts of fishes lie in wait to devour the young turtle; the most notorious offenders in this respect being the "puppy-sharks," young sharks about four feet in length in whose stomachs as many as twenty-five young turtles have been found. It can be seen,

Turtle swimming in breeding pond

Green turtles ready for shipment

therefore, that the mortality rate amongst newly-hatched turtles is unduly high and that but few reach the adult size.

In order to combat this loss, it was the idea of some residents in the West Indies to start a turtle-farm on the island of Inagua, the southermost island of the Bahama group, lying due north from the western part of the island of Haiti. It was the plan of these men to purchase the smaller turtles that had been caught by Magua fishermen and to allow these to grow to marketable size in a sea inlet which had been carefully shut off from the ocean. This inlet, while allowing the tides to enter and leave through sluice gates, was separated from the sea itself by long walls of coral rock. The bottom of the inlet was overgrown with the ulva-grass upon which the green turtle feeds, and numerous fishes in the water provided food for the carnivorous hawksbill turtles. The originators of the turtle farm intended to raise the edible green turtle for live export to markets in the United States, and the hawksbill turtle in order to procure the valuable tortoise shell.

In addition to buying the smaller turtles from the fishermen so as to keep them in the inlet until they reached a marketable size, the turtle-farmers also bought the eggs collected by the turtlers along the beach of the island of Inagua. The eggs were carefully transported in the same sand in which they were found, and then placed in large boxes in the tropical sun. When the young turtles hatched in these novel incubators they were kept in a wooden tub and fed on chopped-up meat or fish, in the case of hawksbill turtles, and on small particles of ulva-grass in the case of green turtles, until they were a few weeks old. The young turtles were then considered old enough to strike out for themselves and were turned out in the nurseries, small enclosures about forty feet square, built on the inside of the sea-wall. These enclosures had been carefully netted over with chicken-wire, in order to prevent birds of prey from carrying off the little turtles. Fishes of the larger size could, of course, not enter the small gaps in the walls surrounding the nurseries and in consequence, with the exception of large crabs which occasionally managed to enter the enclosures and to kill a few of the small animals, the young turtles were safe. They stayed in these nurseries until they reached a size of about five pounds and were then allowed the restricted liberty of the sea-inlet itself.

Whenever the turtle-farmers found it necessary to make a shipment of green turtles it was an easy matter to catch those that were desired, by the simple process of dropping nets over them. The turtles were then "spanseled," i. e., turned on their backs and their flappers tied with cords in order to prevent the animals from hurting each other. The "spanseled" turtles were shipped to New York on the steamers which called at Inagua, and it was found only necessary to pour sea water over the animals a few times daily in order to insure their arrival in good condition. A few years ago the "spanseling" of turtles was prohibited by law through the efforts of the Society for the Prevention of Cruelty to Animals, and in consequence live turtles have now to be shipped in tanks.

Whenever the turtle-farmers received an order for tortoise-shell, such hawksbill turtles as had reached a commercial size were caught in the same manner as the green turtles. They were then killed and buried, and after a few days the tortoise-shell plates could be removed from the carapace and shipped in boxes to the dealers in this commodity.

There can be no doubt that the venture would have been a success had it not been for a hurricane which destroyed part of the sea-wall dividing the inlet from the ocean. As a result of this accident the turtles that were in the inlet betook themselves to the open water, and the owners of the farm were too disheartened, and did not possess enough of funds, to recommence the work. But there can be no doubt that, with proper means and sufficient funds, an industry of this kind could be made highly profitable, especially so if the right kind of inlet were used for the purpose, on an island where a plentiful supply of eggs and small turtles could always be secured.

The Determination of Surface-Tension*

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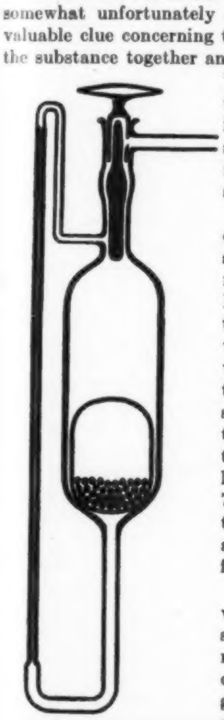
This investigation is part of a series of investigations having for their object the study of the fundamental properties of liquids. It is hoped that, when a number of these properties have been determined with great accuracy, the essential relations between them may be discovered with greater certainty than is possible at present.

Among the significant properties of liquids surface-tension stands out as one of the most interesting. This somewhat unfortunately named property affords us a valuable clue concerning the cohesive forces which bind the substance together and cause it to become a liquid. Therefore, its exact determination is a matter of far-reaching importance to anyone who seeks to understand the fundamental nature of the liquid state.



APPARATUS IN DIAGRAMMATIC SECTION. (THE LOADED SINKER IS TO DIMINISH THE NECESSARY VOLUME OF LIQUID.)

A glance at the published data concerning surface-tension leads one to conclude that much remains to be done. For example, the values obtained by experienced men for water at 20 degrees vary all the way from 70.6 to 78, according to different methods. Even a single method (for example, that of the rise in capillary tubes) has yielded results in the last 25 years varying from 70.6 to 72.7, and no satisfactory evidence is forthcoming as to the reasons for the difference.

It seemed therefore, worth while not only to study the surface-tension of a variety of new liquids, but also to discover the reason for the divergences between different methods, and to obtain results of absolute as well as of relative accuracy for liquids already studied. The present work, although only preliminary, seems to have been successful in locating several of the heretofore not adequately heeded sources of error.

The method chosen was the well-known method of capillary rise in carefully measured tubes, because this method seems to be one of the most direct and least likely to lead to insoluble mathematical complications. The method has been used by many experimenters in the past.

Several features of the present work deserve emphasis. In the first place, the careful selection of the capillary tubes and the calibration by means of short columns of mercury received especial attention. Correction was made for the meniscuses of these columns in determining the exact diameter of the tube. Again, great care was taken to determine exactly the position of the meniscuses, both of the larger and of the smaller surface, by means of a finely adjustable black screen behind the tubes to be measured. It was found that the exact position was only to be observed when the meniscus appeared to be precisely tangent to the edge of the screen.

Both of these precautions have been more or less fully heeded by others; but another precaution, the determination of the diameter necessary for the larger tube in order to secure perfectly flat surface, has been often overlooked. We found that a tube over 35mm. in diameter was required, and that even into this wide tube it was not permissible to insert a capillary; for such an insertion acted as another basis of support for the liquid and caused appreciable rise. By actual measurement we found that the capillary rise in a 20mm. tube, counting only from the middle of the bottom of the meniscus, was over 0.5 mm., and the addition of a capillary tube in the middle of this raised it at least 0.3mm. more. As apparatus of this sort has been used by most experimenters on surface-tension, most of the capillary rises which have been reported are in the neighborhood of 1mm. too low—an error which accounts for a large part of the discrepancies between different methods.

Another error which does not seem to have received sufficient attention is that due to the weight of the liquid in the finer meniscus above its lowest point. The equation of Poisson, which is usually used for calculating this weight, gives an absurd result with tubes as wide as 1cm., and therefore must be rejected. Another equation, that of Desains, gives a result for fine tubes which is not plausible; hence this also seemed unworthy of confidence. A careful measure of the height of the meniscus between its lowest point and its line of contact with the fully wetted walls showed that in very fine tubes this height is almost exactly equal to the radius, and that, therefore, the meniscus is here essentially hemispherical. As the tube widens, the hemisphere becomes somewhat flattened, and for moderate radii it appears entirely safe to apply, as a correction to be added on account of the meniscus, one-third of the meniscus height as actually measured. This method of correction was shown to give consistent results with tubes of different diameters.

Great difficulty and considerable liability for error were found in the inequalities of the glass of the tubes to be measured. Accordingly all measurements were made in reversible apparatus of the type shown in the diagram. This form of apparatus when exactly half filled with liquid is observed, first in an upright position in front and behind, and again in an inverted position in front and behind. Thus from the average, all the displacements due to refraction of irregular walls of the larger tube are entirely eliminated. The regularity of the walls of the smaller tube are fully tested by the calibration.

The preliminary results thus obtained are recorded in the table given below. All the measurements were made in the presence of air. The surface-tensions are calculated according to the well known equation $\gamma = \frac{1}{2} rhg (s_1' - s_2)$ in which the angle of contact of the meniscus in the tube is assumed to be zero.

It will be noted that, in general, these results are higher than most of the earlier results, for the reasons already suggested. For example, Quincke found only 14.47 as the capillary constant of water, and Renard and Guye found 6.47 for that of benzene. The carefully obtained results of Walden and Swinne, although measured in a fairly satisfactory apparatus, are all subject to the same error, because the apparatus was calibrated by means of a value of capillary constant of benzene which is too low.

Data obtained with Apparatus III (20.00°)

Radius of capillary = 1.0099 mm.

Substance	Average height in mm.	Correction for small meniscus	Corrected height in mm.	Density 20°/4°	Capillary constant a^2	Surface tension dynes per mm²
Water............	14.394	0.321	14.715	0.99823	14.861	72.62
Benzene..........	6.351	0.311	6.662	0.8788	6.728	28.94
Toluene..........	6.369	0.311	6.680	0.8658	6.736	28.58

Data obtained with Apparatus IV (20.00°)

Radius of capillary = 0.1936 mm.

Benzene..........	34.620	0.061	34.681	0.8788	6.714	28.89
Methyl alcohol.....	30.063	0.061	30.124	0.7918	5.832	22.61
Ethyl alcohol.......	29.720	0.061	29.781	0.7892	5.766	22.27
Isobutyl alcohol....	30.016	0.061	30.077	0.8019	5.823	22.86
Ethyl butyrate.....	29.403	0.061	29.464	0.8789	5.704	24.53

This paper is only a preliminary communication. A fuller report of the work will appear in the July number of the *Journal of the American Chemical Society*. Much more work upon the subject has already been finished, and yet more is in prospect.

Summary.—In the course of a series of determinations of capillary constants by measuring the capillary rise in fine tubes, the following precautions have been especially emphasized: (1) The detection and correction of inequalities in the glass tubes employed were effected by the use of a reversible apparatus. (2) Reference of the capillary rise was made to an unrestricted flat surface 38mm. in diameter, the largest ever used. It was shown that much smaller surfaces are too small and that the insertion of a capillary in the middle of a larger tube causes appreciable error by increasing the capillary effect of the large tube. (3) Especial care was taken that the true bottom of the meniscus should be read. (4) The weight of the fine meniscus was in each case allowed for, and a new approximate formula was suggested for its calculation, depending upon the observed height of the meniscus.

Heeding these precautions, determinations of the capillary constants of several important liquids were determined at 20 degrees as follows: water 14.861, benzene 6.721, toluene 6.736, methyl alcohol 5.832, ethyl alcohol 5.793, isobutyl alcohol 5.823, ethyl butyrate 5.704.

*From the proceedings of the National Academy of Science.

Substitutes in the German Electrical Industry*

Old Materials Used in New Ways and New Materials Devised

THE search for substitutes in this country since the war began has been mainly directed to the replacement of German manufactured articles. We were suddenly cut off from a great part of our supplies of dyes, lenses, synthetic drugs, the rarer metals, and many other things, and had to provide them for ourselves. Up to the end of last year we did not suffer greatly from want of raw materials, and our present scarcity is largely due to our supplying the needs of our Allies. In Germany, the case was different, for the blockade acted mainly against the entrance of raw materials. It is, of course, far more difficult to replace a raw material than to inaugurate a new manufacture for which the materials are available. The straits to which the German electrical industry have been reduced have lately been portrayed before a meeting of the Swedish Electricity Works by Chief Engineer M. T. Husberg. He had a sympathetic audience, for Sweden has been very badly hit in the same way, and this has happened when the great hydro-electric stations were not completed, and were specially wanted on account of the high price of coal.

The Germans, as soon as war had commenced, took up the question of substitutes in their usual systematic way, and the electro-technical industry may be said to have taken the lead in this connection. As early as the latter portion of 1914, when the government requisitioned copper, rubber and other raw materials, special commissioners were appointed to deal with these matters. To obtain any suitable substitutes at all it was often necessary to fall back upon other materials which were not by any means plentiful, although less scarce than the usual materials. The first task was accurately to ascertain the quality and adaptibility of the possible substitutes, and to what extent the normal regulations had to be altered and the normal demands modified.

The greatest difficulty which the electrical industry had to face in Germany was the shortage of copper and its alloys. The comparatively small quantity of these metals which could be produced within the country had, almost entirely, to be reserved for military purposes. Also the supply of aluminum has been somewhat limited, large quantities being needed for the construction of aeroplanes and other war munitions. Also of lead, nickel and tin there has been a very considerable shortage; zinc has been fairly plentiful, as have also iron and steel. Endeavors have, therefore, been made to use zinc instead of copper, where iron was out of the question, and only to use aluminum where zinc could not be used. The following table contains some particulars as to the qualities of metals in question:

—	Conductivity.	Specific Gravity.	Melting-point in Deg. C.	Coefficient of Thermal Expansion per Deg. C.
Copper	57.0	8.9	1,084	1.7×10^{-5}
Aluminium ..	32.7	2.7	657	2.2×10^{-5}
Magnesium ..	22.0	1.7	630	3.2×10^{-5}
Zinc	16.0	7.2	420	3.0×10^{-5}
Electron—				
Cast	16.0	1.8	620	—
Pressed ..	16.0	1.8	620	—
Iron	7.0	7.8	1,400	1.2×10^{-5}
Steel	5.8	7.7	1,350	1.2×10^{-5}

The electro-technical industry had so exclusively confined itself to copper conductors, with some slight use of aluminum, that before the autumn of 1914 the practical adaptibility of the other metals had hardly been investigated. Up to that time such metals as zinc and magnesium had not been produced commercially as wire. The Germans at once began to investigate the best possible methods of production, and within comparatively short time, they achieved very notable results. Nevertheless for many purposes copper remained indispensable.

Zinc was first taken in hand, and both its natural unfavorable qualities and the difficulties of manufacture were reduced. The manufacture of drawn zinc wire was soon attained, and its brittleness and sensitiveness to change of temperature to some extent reduced. The purest metal was selected and it was shaped in the first instance by a squirting process. Under a pressure of as much as 500 atmospheres the zinc was extruded in a cylindric shape, which was afterwards drawn into wire. At first, zinc bars were made by cutting them out of rolled plate, but by squirting and pressing, bars of improved qualities were obtained. Although zinc conductors still have a relatively low strength and a low melting-point, they prove a practicable substitute for certain purposes, such as bus-bars, conductors and apparatus, and in some cases even for machine windings. In many cases, however, the low conductivity of zinc makes it unfit to serve as a substitute for copper. Its ductility is fairly satisfactory, inasmuch as wires of 1 mm. to 3.5 mm. in diameter can be bent 20 times over a rod before breaking. Soldering of zinc is difficult, and must be done cautiously, as its melting-point is still lower than that of aluminum.

Aluminum was already, before the war, so widely used that its qualities and the most efficient method of manufacture were fairly well known, as were also the difficulties and drawbacks connected with its use, such as its low tensile strength and somewhat low melting-point. Yet aluminum, whose conductivity is twice that of zinc, is a really valuable substitute for copper in the construction, both of conductors, machines and apparatus. Even before the war, in the year 1913, the world's consumption of aluminum for conducting purposes was estimated at 10,000 tons per annum. Since then the mode of manufacture has been improved, amongst other ways by a careful cleansing of the raw material, so that both overhead lines and windings of a considerable increased flexibility are now produced.

Moreover, several alloys of aluminum have been further investigated and improved, and new alloys have made their appearance. In this connection mention should be made of electron (10 per cent. aluminum, 90 per cent. magnesium), magnalium (90 per cent, aluminum, 10 per cent. magnesium) and duralumin (91 per cent. aluminum, 9 per cent. copper). These alloys, besides pure magnesium, whose conductivity lies between that of zinc and aluminum, are principally used for bus-bars and heavier bar connections, and as castings in apparatus for high voltage. For purposes where an entirely non-magnetic material is required, electron is much used.

The Germans have made extensive use of iron for electric conductors, and have made elaborate researches to reduce its drawbacks arising from its small conductivity, the troublesome skin effect with alternate current transmission if the lines are too thick, and its tendency to rust if the lines are too thin. Special wires have been formed with a core of steel and outer layers of better conductors. Much attention has also been given to different methods for protecting iron wire, first and foremost by zinc, but in some cases also by a copper coating. Such coatings serve for the conductor in insulated lines.

As the three most important metals—aluminum, zinc and iron—began to be more extensively used as substitutes for copper in electric conductors, it was proposed to introduce the word "kaze," as a reminder of the four metals, copper (Kupfer), aluminum, zinc and iron (Eisen) ore being numbered in the proper order, and that each metal has a conductivity that is very roughly double that of the subsequent one.

In insulating materials the shortage has been most pronounced in rubber, cotton, jute, oil, asbestos and mica, and a number of more or less satisfactory substitutes have been produced and put to the test. Paper, first and foremost, has been extensively used in different forms and compositions. It has been spun into yarn and impregnated. It takes the place of jute and hemp in underground cables, and replaces cotton and rubber on transmission wires and in coils. A more valuable substitute for rubber has been found in regenerated rubber, that is, refined rubber residue. This substitute is improved in certain works by being amalgamated with bitumen or other tar substances which make it elastic. A substitute for hard rubber is furnished by an artificial product of phenol and formaldehyde, called Faturan. It is not hygroscopic and can, it is asserted, be compounded so as to be fireproof and acid-proof. Other similar substances are wenjacite and aswelite, the latter having been brought out by the Siemens-Schuckert Company. As a substitute for oil in electric apparatus the firm of Voigt and Haeffner have brought out what they call Benzinoform, a tetra-chloride-carbon substance, which will not burn, but the experiences so far have not been quite satisfactory, inasmuch as the material is too volatile.

As regards the practical uses to which the different substitutes referred to above have been put in Germany during the war, the subjoined table throws some light upon the position before the war and at present:

Appliances.	Substances Used. Before the War.	At Present.
Overhead conductors	Copper wire ..	Iron wire.
		Composite iron and zinc.
		Composite iron and aluminium.
		Aluminium and paper, &c.
Insulators and insulated conductors.	Hemp, jute.. ..	Conductors with paper insulation and iron, zinc or aluminium conductors.
	Ordinary vulcanised conductors, single or otherwise	Rubber insulated zinc or aluminium conductors.
	Flexible for movable connections	Flexible iron wires.
	Cables, with or without armouring, with vulcanised rubber and lead covering	Cables with paper insulation and thinner lead covering.
Apparatus such as lamp-holders, switches, safety appliances, &c.	Copper, brass, tombac	Iron, zinc, aluminium.
Resistances. ..	Copper, nickeline ..	Manganine, iron, water resistances.
Bus-bars	Copper	Iron, zinc, elektron, magnesium.
Machines	Copper and cotton..	Zinc, aluminium, iron, paper yarn.
Belting	Leather	Paper, steel bands.
Lubrication ..	Oil	Graphite oil, solution with potash.

All the above new substances have been subjected to auxiliary regulations and alterations in the German *Verbandsnormalien*.

For overhead conductors iron is principally being used. With alternate current and over large areas, when stranded wires have to be used, the separate wires in the cable are not as a rule of less diameter than 1.5 mm., for fear of them rusting through, nor of more than 3.00 mm., so that the skin effect may not be too serious. The method of manufacture plays an important part as regards diminishing the skin effect, and the hardness of the steel, or the iron, is also of some moment, inasmuch as the skin effect is reduced with an increased strength. If, however, the metal is too hard, the specific resistance is increased.

Special regulations, based upon careful tests, have also been proposed for composite conductors. The outer layer, outside the galvanized steel wire, is mostly made of zinc wires, and such conductors have worked exceedingly satisfactorily. With alternate current they have but slight skin effect, as shown by some special tests; an iron conductor of 70 sq. mm. area was compared with a composite conductor of 50 sq. mm. area; both had about the same Ohmic resistance; at 70° the former had 39 per cent. increase in resistance, the latter 22 per cent. Firms like Felten and Guillaume and the Bergmann concern have taken up the manufacture of these conductors with areas from 2.5 sq. mm. to 150 sq. mm. Composite conductors with an outer layer of aluminum naturally show a better conductivity, and they are resorted to when the iron-zinc cables are no longer adequate. Such conductors have also been used in America for some years with good results.

Overhead conductors of zinc alone are not likely to be used, although zinc wires of best quality have proved serviceable with very short distances between the poles. If iron or zinc conductors are laid under ground, they must be lead-coated or in some other way protected against corrosion. The regulations prescribe a number of precautions to be observed at the junctions of overhead conductors, especially as regards connections between wires of different metals.

Insulated Lines.—As early as December, 1914, the first regulations were drawn up concerning the method of manufacture of insulated wires, to remain in force until further notice. These regulations applied to insulated conductors and the wires, other than copper, were to be of aluminum or flexible tinned, galvanized or lead-coated iron, with a conductivity at least 7. Single conductors were not to exceed an area of 16 sq. mm., and stranded conductors an area of 6 sq. mm. for each wire. If of copper or aluminum they might be solid up to 16 sq. mm. area; if of iron up to 2.5 sq. mm. area. Multiple conductors were to comprise a minimum of seven wires of 1.4 mm. maximum diameter. The conductors were to be surrounded with a well-impregnated paper cover of from 0.8 mm. to 1.2 mm. thickness, according to the cross-section of the conductor. Outside the paper coating was to be spun a covering of cotton, hemp, etc. The surface cover

*From *Engineering*.

was to consist of a non-corrodable metal envelope (not lead) of at least 0.25 mm. thickness. Insulated conductors of this description were only to be used for low voltage and in dry premises, where they were to be visible. Insulated conductors, made in this manner, but fitted with a leaden envelope, might be used in damp premises, if fixed visibly. The current density on the iron conductors was to be about in the proportion of 1:2.8 to that permissible for copper.

In March, 1915, the regulations were altered for insulated wires with paper coverings, inasmuch as zinc was admitted as a conducting material, zinc being allowed to be used solid up to 16 sq. mm. area. The smallest permissible areas were then modified to be 1 sq. mm. for copper and aluminum, 1.5 for zinc, and 2.5 for iron.

The coated conductors, however, could not in all respects serve as substitutes for the ordinary vulcanized lines, which soon became more and more scarce from shortage of copper and rubber. Regulations were therefore published, also in March, 1915, for conductors of zinc with an insulating layer of a rubber composition, to be used for low-voltage installations on fixed apparatus. This rubber was manufactured with the greatest care from regenerated products. Inasmuch as regards elasticity and durability, this material cannot vie with ordinary vulcanized rubber, it was ordered, to begin with, that the layer should have a thickness of at least 1.5 mm. instead of 0.8 mm. These "rubber-insulated" conductors are, when solid, of 1 5 sq. mm. to 6.0 sq. mm. areas, and when multiple, of 1.50 sq. mm. to 150.00 sq. mm. areas. The conductivity must be at least 15.

Some time later it was announced that in spite of many applications iron could not be admitted in the above-mentioned conductors, because the wires were so stiff, and damaged the regenerated rubber insulation. Only zinc, of the most pliable kind (besides copper and aluminum) can therefore be used for the new "rubber conductors." The minimum thickness of the rubber layer was at the same time reduced.

In August, 1915, it was arranged with the manufacturers that all conductors of zinc and regenerated rubber should have a light green marking thread, so that they could be known from ordinary vulcanized wires. For flexibles the insulating cover could be made of regenerated rubber and the conductor of fine iron wire, with a cross-section from 2.5 sq. mm. to 4.0 sq. mm.

In the beginning of 1916 it was announced that when insulating tubes of paper were enclosed in an unwelded tube, the latter might be covered with zinc instead of lead, the zinc coating to be thick. Regulations for aluminum conductors in rubber-insulated lines followed in March, 1916, both for stationary and movable purposes. In September, 1916, when the shortage of raw materials had become still more pronounced, it was prohibited to use outer coverings of cotton on "rubber insulated" zinc and aluminum conductors of 16 sq. mm. or more, permission being at the same time given, for similar conductors, to have an inner paper-yarn coating round the separate wires instead of rubber-impregnated windings. At the same time the demands as to copper were modified, so that its resistance might amount to 20 ohms per kilometer of 1 sq. mm. section at 20 deg. C., corresponding with 19.6 ohms at 15 deg. C., instead of 17.5 ohms as otherwise used.

That the current density in insulated conductors of substituted metals is relatively high will appear from the following table, which shows that stranded conductors indoors, protected by 6 A safety fuses, if of copper may have an area of 1 sq. mm., if of aluminum also 1 sq. mm., if zinc 1.5 sq. mm., and if of iron 2.5 sq. mm.:

Load in Amperes

Area in Square Millimetres.	Copper. Strength of Current.		Aluminium. Strength of Current.		Zinc. Strength of Current.		Iron. Strength of Current.	
	1.	2.	1.	2.	1.	2.	1.	2.
	amp.	amp.	amp.	amp.	amp.	amp.	amp.	amp.
1.0	11	6	8	6	—	—	—	—
1.5	14	10	11	6	9	6	—	—
2.5	20	15	16	10	11	6	8	6
4.0	25	20	20	15	13	10	10	6
6.0	31	25	24	20	16	10	12	10
10.0	43	35	34	25	23	20	17	15
16.0	75	60	60	35	40	35	30	25
25.0	100	80	80	60	52	35	—	—

1 represents the permissible current; 2 the normal current

Many warnings have been uttered against these conducting materials, however pressing the reasons have been for adopting them. On the whole, however, experience appears to have been favorable, and the fact that the regulations for these new types have been laid down by the Society of German Engineers offers in itself a guarantee for their safe use. Tests show that zinc conductors, principally on account of the larger quantity of material required for the same strength of current, are not exposed to any greater risk of melting than are copper wires.

Installation Material and Instruments and Apparatus.—Substitute metals have proved very serviceable for instruments and apparatus. It has already been mentioned that zinc, aluminum and its alloys are well suited for bus-bars and fittings. Iron, too, has been used for such purposes, but in such cases the bars must be divided in a suitable manner, when dealing with alternate current. Iron and zinc are now normally used for lamp-holders, wall contacts, cable shoes, switches A, for safety apparatus up to 350 A, starting and regulating resistances up to 100 A. etc. As regards starting resistances, water has again come into vogue.

When the metals referred to do not possess sufficient conductivity, aluminum is resorted to as a substitute. All movable parts of contacts and contact arrangements with springs exposed to light arcs, however, must be of copper or be coated with copper or a copper alloy. Zinc and aluminum have too low a melting-point for such purposes.

As regards switches and other apparatus for the instrument house, where it is a question of currents of considerable strength, the experiences of the last year show that, even in such, iron and zinc can often with advantage be used in the principal parts. Separate regulations have been drawn up for special metals to be used as substitutes in the various meters and measuring instruments.

Machines and Transformers.—The Germans first tried zinc in transformer windings and afterwards also in machine windings, and iron was used in commutators. A standardized machine manufacture with such substitute parts is now in full operation. Experience has shown that compared with equally large normal machines of copper the following substitutes develop:

	Per Cent. Efficiency.
Transformers with zinc windings	60
Three-phase motors	40–60
Continuous-current machines, with field winding of zinc, commutator of iron, and armature winding of copper	80
Continuous-current machines, with both windings of zinc and commutator of iron.. ..	50

All machines with substitute metals naturally have relatively low efficiency, in the same way as three-phase motors have a lower load factor:

Machines up to about 1,000 Revolutions.	Stator Winding.	Rotor Winding.	Slip-ring or Commutator.
Asynchr., three-phase motor (100 volts to 5,000 volts)—			
Below 0.3 kw.	Copper	Copper	—
From 0.3 kw. to 10 kw. ..	Aluminium	Zinc or Aluminium	Iron
From 10 kw. to 80 kw. ..	Zinc.	Zinc.	Iron
From 80 kw. to 175 kw...	Aluminium	Aluminium	Iron
Above 175 kw.	Aluminium	Optional	Optional
Synchr. three-phase machine (100 volts to 5,000 volts)—			
Up to 70 k.v.a.	Zinc	Zinc	Iron
From 70 k.v.a. to 250 k.v.a.	Aluminium	Aluminium	Iron
Above 250 k.v.a. ..	Optional	Optional	Iron
Continuous-current machine (100 volts to 500 volts)—			
Below 2 kw.	Copper	Copper	Copper
From 2 kw. to 10 kw. ..	Aluminium or Copper	Copper	Iron
From 10 kw. to 35 kw. ..	Aluminium	Aluminium	Iron
From 35 kw. to 175 kw...	Zinc or Aluminium	Aluminium	Iron
Above 175 kw.	Aluminium	Copper	Copper

Three-phase Transformer up to 30,000 volts.	Windings according to Voltage.		
	Up to 15,000 volts.	15,000 volts to 20,000 volts.	20,000 volts to 30,000 volts.
Capacity up to—			
15 k.v.a.	Aluminium	Aluminium	Aluminium
15 k.v.a. to 25 k.v.a.	Zinc	Aluminium	Aluminium
25 k.v.a. to 50 k.v.a.	Zinc	Zinc	Aluminium
50 k.v.a. to 250 k.v.a.	Zinc	Zinc	Zinc
Above 250 k.v.a.	Aluminium	Aluminium	Aluminium

Of late the supply of aluminum in Germany has been on the increase, for which reason, in order to improve the machines, windings of this metal have been adopted in some cases. In machines and transformers made in this way, the efficiency is stated to be only 20 per cent. short of the normal. The above tables show the German regulations for the use of substitutes in machines and transformers. Where it is a question of machines for special purposes and whose reliability of working is of particular importance, the normal mode of manufacture may still be used. Machines and transformers with copper or aluminum windings are, according to the new regulations, allowed to rise to a temperature 10 per cent. higher than that which was normally permitted.

Ball bearings have been generally adopted so as to save the expensive copper alloys for the usual bearings, and so as to reduce the consumption of lubricants.

The different German commissions dealing with the matter of substitutes in the electric industry continue to publish regulations and directions. There are also new regulations for overhead lines tending, in some respects, to increase the permissible strain on the constructive parts; also for the use of different substitutes in instrument transformers of various kinds. Based upon the most recent experiments the regulations as regards materials for conductors, especially zinc conductors, have been revised, both for insulated and bright lines.

It will be gathered from what has been said above that substitutes have become of the greatest importance to the German electric industry, and the point of special interest is to be found in the fact that the use of substitutes has become so extended, although it has been carefully regulated by special rules. The representatives of the high-voltage transmission seem to have found out, to their own surprise, that in many cases satisfactory results could be obtained by means of materials, which they would never have thought of employing before the war. It has, however, in some ways been comparatively easy to carry on all these tests in a thoroughly rational manner, inasmuch as the question of cost has not been much considered during the war. Satisfaction has, on several occasions, been expressed at old-rooted prejudices now having been overcome, prejudices which formerly unnecessarily increased the cost of electric plant and equipment.

Another point should be mentioned in connection with the electric industry in Germany during the war. In spite of the serious shortage of the old, and for the matter of that, though to a smaller extent, some of the substitute raw materials, the electricity industry has worked, if anything, with increased energy. From the standpoint of national economy it is more advantageous to produce energy on a large scale for the really necessary requirements, than to produce it in isolated heat motors and to use gas or petroleum for lighting.

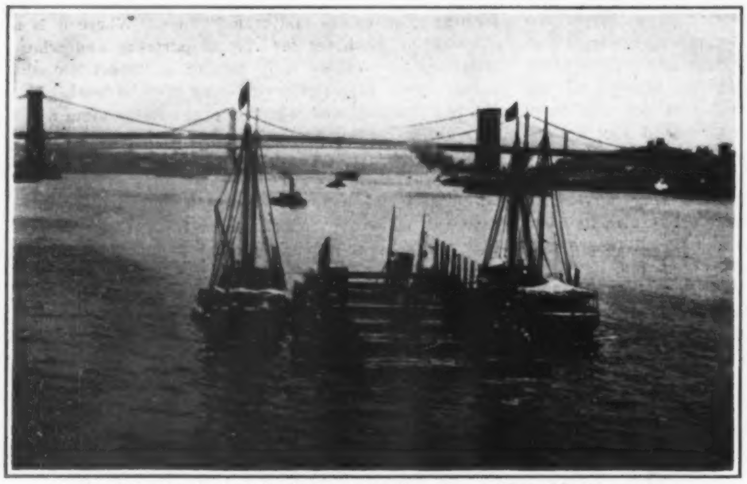
A Monument to the Hun

Among their other activities the Germans have been busily engaged in erecting a vast series of monuments commemorative of their true character and their methods. These are the shattered wrecks of the magnificent cathedrals and other notable public buildings in all parts of Belgium, and in France, which the Huns have deliberately, wantonly and ruthlessly destroyed.

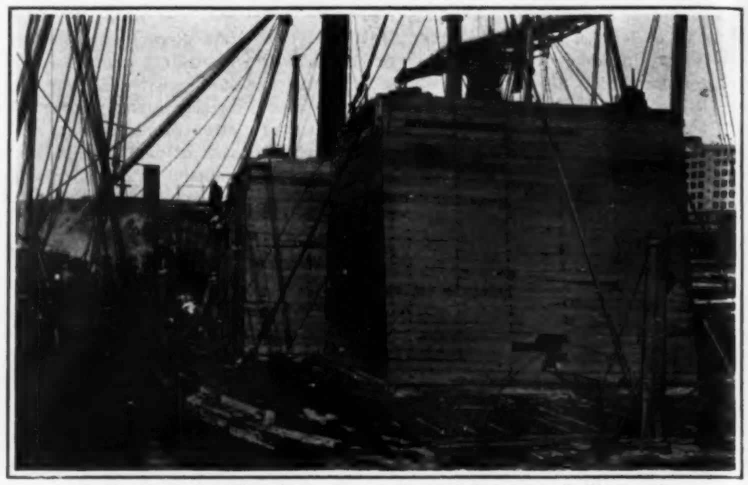
As noble specimens of architecture their like will never be seen again, for they were the creation of a race of artists and artisans who no longer exist, and in many instances they represent the patient labor of hundreds of years. Even if detailed drawings of any of these edifices have been preserved, it would be impossible to restore them acceptably, for that intimate character, which lent so much to their charm, would be lacking, and their modern origin would be indelibly stamped upon them.

The Hun of ancient times might have had the excuse of ignorance for the wanton destruction he delighted in, but the modern Hun can set up no such pretext. His sordid soul knows full well the value of what comes into his possession, and he destroys only what he cannot carry away. No one will ever know what untold treasures of art have been looted from the stricken cities of Belgium, both from public buildings and from private houses alike, by the German hordes; and in this work there has been no distinction between the princes of the land and the lowest of camp followers.

The purpose of Germany has clearly been to devastate Belgium absolutely, its people as well as its property, to make room for still more numerous broods of its own barbarous race; but the humble graves of their human victims will in time disappear from sight and memory. Something of the solid ruins of the beautiful historic cathedrals will, however, remain, and it is to be hoped that suitable portions of these will be carefully preserved as memorials of stricken Belgium and its people, and to remind the world for ages to come of the crimes of Germany and as a warning against a nation whose solemnest pledges are valueless and who is ever ready to attack friend or foe for commercial profit.



A simple method of raising ships is to sling them at low tide to pontoons placed on either side



Coffer dam extending above the surface of the water, built over the hatches of a sunken vessel

The Salvage of U-Boat Victims*—I

Methods by Which Many May Be Recovered After the War

By A. Russell Bond, Managing Editor of the Scientific American

When the grim harvest of death is over and the peoples of war-torn Europe turn again to the walks of peace, there will be rich gleanings in the debris strewn over the great battlefields. The humble French peasant may return to his farm to look in vain for his vineyard and find an iron mine in its stead; for in places the iron storm has raged incessantly for weeks and the ground is drenched with steel. Even where the hail of shells and rifle bullets has not been very heavily concentrated a people so thrifty as the French, and so ingenious at coining money from waste may be depended upon to recover respectable values from the desolated lands.

But the richest spoils of the war are to be found in the sea; for here we have great ships filled with valuable cargoes and rich treasure, awaiting the salver who is bold enough to venture into the cruel grip of deep water. There is no doubt that the business of salving wrecked and sunken vessels will receive an unprecedented impetus after the war. According to figures recently given out by the British Admiralty, twelve million tons of allied and neutral shipping had been sent to the bottom during the war, up to January 1, 1918. The value of a ship used to be estimated at $125 per ton. This figure has nearly tripled and there has also been a great increase in the value of cargo, so that $500 per ton is taken as a fair average for the value of a ship and its cargo. On this basis almost six billion dollars worth of ships and cargo lie at the bottom of the sea. More than half of this loss was incurred within the past year when 6,628,623 tons of shipping were destroyed—this means an average daily loss of nearly one million dollars.

Not all of these ships were sunk in deep water—many torpedoed vessels were beached, or succeeded in reaching shallow water before they foundered. Some were sunk in harbors before the precaution was taken of protecting the harbors with nets. In one of the chief European ports submarines entered and sank seven ships.

The salvage of vessels in protected waters will not have to wait until the end of the war. Already much salvage work has been done by private wrecking concerns and now our Government has taken a hand in the work. All the wrecking equipment in this country has been commandeered by the Government and we have already sent over to the other side experienced American salvors, provided with complete equipment of apparatus and machinery.

The majority of wrecks, however, are found in the open sea, where it would be foolish to attempt any salving operations because of the menace of submarine attack. These wrecks will have to wait until the end of the war. Such of them as lie in shallow water, if not in exposed positions no doubt can be raised by the ordinary methods, or if it is impracticable to raise them, much of their cargo can be reclaimed. However, most of the torpedoed ships lie at such depths that their salvage would ordinarily be despaired of.

It will be interesting to look into conditions that exist in deep water. Somehow the notion has gone forth that a ship will not surely sink to the very bottom of the deep sea, but on reaching a certain level will find the water so dense that even solid iron will float, as if in a sea of mercury, and here the ship will be maintained in suspension, to be carried hither and yon by every chance current. Indeed it makes a rather fantastic picture to think of these lost ships drifting in endless procession, far down beneath the cold green waves, and destined to roam forever like doomed spirits in a circle of Dante's Inferno.

Unfortunately the laws of physics shatter any such illusion and bid us paint a very different picture. Liquids are almost incompressible. The difference in density between the water at the surface of the sea and that at a depth of a mile is almost insignificant. If we could go down to the spot where the "Titanic" lies on the bed of the ocean, two miles below the surface, and bottle a sample of water in an absolutely inelastic quart flask, on returning to the surface we should find when the stopper was removed that the water would expand slightly and overflow the container, but the overflow would amount to less than a tablespoonful. Putting it another way, water at a depth of a mile would support about half a pound more per cubic foot than at the surface. The water pressure on the "Titanic" is about two long tons on every square inch of its surface. Long before the vessel reached the bottom her hull must have been crushed in. Every stick of wood, every compressible part of her structure and of her cargo must have been staved in or flattened except where the pressure was counteracted by permeation with water of equal pressure. As a ship sinks it is not the water but the ship that grows progressively denser. The "Titanic" must have actually gained in weight in proportion to her displacement as she went down, and so she must have gathered speed as she sank.

A powerful electro-magnet used to recover iron and steel objects from sunken vessels

We may be certain, therefore, that every victim of Germany's ruthless U-boats that sank in deep water lies prone upon the floor of the sea. It matters not how or where it was sunk, whether it was staggered by the unexpected blow of the torpedo and then plunged headlong into the depths of the sea, or whether it lingered, mortally wounded, on the surface, quietly settling down until the waves closed over it. Theoretically, of course, a perfect balance might be reached which would keep a submerged vessel in suspension, but practically such a condition is next to impossible. Once a ship has started down she will keep on until she reaches the very bottom, whether it be ten fathoms or ten hundred.

Instead of the line of wandering spectors then we must conjure up a different picture, equally weird—an underworld shrouded in darkness; for little light penetrates the deep sea. Here in the cold blackness on the bed of the ocean, the wrecks of vessels that once sailed proudly overhead lie still and deathly silent; some heeled over on their sides, some turned turtle, and many on even keel. Here and there may be one with its nose buried deep in the mud, and in the shallower waters we may come across one pinned down by the stern, but with its head buoyed by a pocket of air, straining upward and swaying slightly with every gentle movement of the sea, as if still alive.

Will it be possible to reach this submarine graveyard and reclaim these lost vessels?

The raising of wrecked vessels is really a branch of engineering, a very special branch—to be sure, and one that has not begun to receive the highly concentrated study that have such other branches as tunneling, bridge construction, etc. Nevertheless, it is engineering and it has been said of the engineer that his abilities are only limited by the funds at his disposal. Here will be a chance to demonstrate the truth of this statement, for there will be hundreds of vessels to be salved where before there was but one.

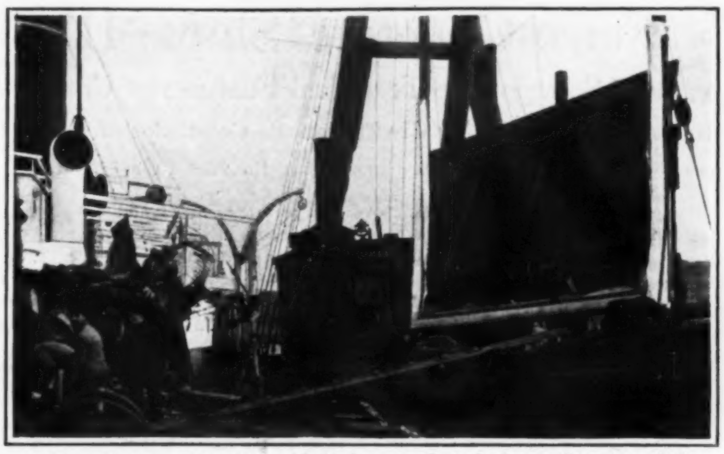
We may expect that under the spur of handsome rewards, astonishing feats of daring will be performed. The vast number of wrecks in deep water will make it pay to do the work on a larger and grander scale than has been possible heretofore. Special apparatus that could not be built economically for a single wreck will be constructed with profit if a number of vessels demanding similar treatment are to be salved.

Right here let me sound a note of warning. Many absolutely impractical salvage schemes are being promoted. Wrecking companies are being formed whose sole purpose is to sell stock. They are hunting for treasure not in the sea, but in the savings banks.

The principal fields of German activities have been the Mediterranean Sea and the waters surrounding the British Isles. Although the submarine zone covers some very deep water where the sounding lead runs down two miles without touching bottom—obviously more havoc could be wrought near ports where ves-

*A lecture delivered before The American Institute of the City of New York, Polytechnic Section.

sels must follow a prescribed course, and so most of the U-boat victims have been stricken when almost in sight of land. In fact, it was not until efficient patrol measures made it too hot for the submarines that they pushed out into the open ocean to pursue their nefarious work. The "Lusitania" went down only eight miles from Old Head of Kinsale, in fifty fathoms of water. If we draw a line from Fastnet Rock to the Scilly Islands and from there to the westernmost extremity of France, we enclose an area in which the German submarines have been particularly active. The soundings here run up to about sixty fathoms in some places, but the prevailing depth is less than fifty fathoms. In the North Sea, too, except for a comparatively narrow lane along the Norwegian coast, which, by the way, marks the safety lane of the German blockade zone, the chart shows fifty fathoms or under. If our sailors could reach down as far as that, most of the submarine victims could be reclaimed. But fifty fathoms means 300 feet, which is a formidable depth for salvage work. Only one vessel has ever been brought up from such a depth and that was a small craft, one of our submarines, the "F-4," which sank off the coast of Hawaii 3 years ago.



A heavy timber patch, with padded edges, ready to be lowered to stop a hole in a ship's side

There are four well-known ways of raising a vessel that is completely submerged. Of course, if the ship is not completely submerged the holes in her hull may be patched up and then on pumping out the hull the sea itself will raise the ship, unless it be deeply embedded in sand or mud. If the vessel is completely submerged, the same process may be resorted to, but first the sides of the hull must be extended to the surface to keep the water from flowing in as fast as it is pumped out. It is not usual to build up the entire length of the ship. If the deck is in good condition it may suffice to construct coffer-dams or walls around several of the hatches. But building up the sides of a ship or constructing coffer-dams on the ship's deck is a difficult task, at best, because it must be done under water by means of divers.

A record for this type of salvage work was established by the Japanese when they raised the battleship "Mikasa" that lay in some eighty feet of water. Her decks were submerged to a depth of forty feet. It is doubtful that this salvage work could be duplicated by any other people of the world. The wonderful patriotism and loyalty of the Japanese race was called forth. It is no small task to build a large coffer-dam strong enough to withstand the weight of forty feet of water, or a pressure of a ton and a quarter per square foot, even when the work is done on the surface. Perfect discipline and organized effort of the highest sort were required. Labor is cheap in Japan and there was no dearth of men for the work. Over one hundred divers were employed. In addition to the coffer-dam construction much repair work was necessary. Marvellous acts of devotion and heroism were displayed. It is rumored that in some places it was necessary for divers to close themselves in, cut their air supply pipes and seal themselves off from the slightest chance of escape; and that there were men who actually volunteered to sacrifice their lives in this way for their beloved country and its young navy. Where, indeed, outside of the "Flowery Kingdom" could we find such patriotic devotion!

A sea sledge in which a diver can be towed under water for exploring purposes

A second salvage method consists in building a coffer-dam not on the ship, but around it, and then pumping this out so as to expose the ship as in a dry dock.

A submarine resting chamber, located near their work, makes frequent trips to the surface by divers to recuperate unnecessary

Such was the plan followed out in recovering the "Maine." Obviously, it is a very expensive method and is only used in exceptional cases, such as this, in which it was necessary to make a post-mortem examination to determine what caused the destruction of the vessel. Neither of these methods of salvage will serve for raising a ship sunk in deep water.

A salvage system that has come into prominence within recent years consists in pumping air into the vessel to drive the water out, thus making the boat light enough to float. This scheme is applicable only when the deck and bulkheads of the boat are substantially constructed and able to stand the strain of lifting the wreck, and when the hole that sank the vessel is in or near the bottom, so as to allow enough air space above it to lift the boat. The work of the diver in this case consists of closing hatches and bulkhead doors, repairing holes in the upper part of the hull, and generally strengthening the deck. It must be remembered that a deck is built to take the strain of heavy weights bearing down upon it. It is not built to be pushed up from beneath, so that frequently this method of salving is rendered impracticable because the deck itself cannot stand pressures that are the reverse of normal.

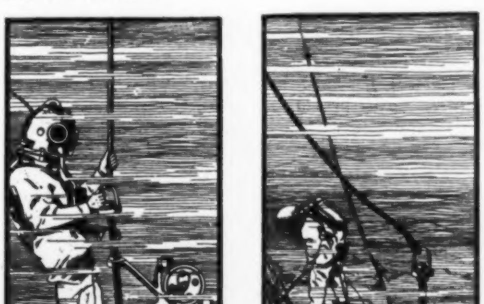
A more common salvage method consists in passing cables or chains under the wreck and attaching them to large floats or pontoons. The slack in the chains is taken up when the tide is low, so that on the turn of the tide the wreck will be lifted off the bottom. The partially raised wreck is then towed into shallower water, until it grounds at the next low tide, when the slack of the chains is again taken in, and at flood tide the wreck is towed nearer toward land. The work proceeds step by step until the vessel is moved in-shore enough to bring its decks awash; when it may be patched up and pumped out. Where the rise of the tide is not sufficient to be of much assistance, hydraulic jacks or other lifting apparatus are used.

If the salver could always be assured of clear weather his troubles would be reduced a hundredfold, but at best it takes a long time to perform any work dependent upon divers, and the chances are very good, when operating in an unsheltered spot, that a storm may come up at any time and undo the work of weeks and months of labor. This is what happened when the submarine "F-4" was salved. After a month of trying effort the submarine was caught in slings hung from barges, lifted 225 feet and dragged within a short distance of the channel entrance of the harbor, where the water was but fifty feet deep. But just then a violent storm arose which made the barges surge back and forth and plunge so violently that the forward sling cut into the plating of the submarine and crushed it. The wreck had to be lowered to the bottom and the barges cut free. At the next attempt to raise the "F-4" pontoons were again used but instead of having them float on the surface, they were hauled down to the wreck and made fast directly to the hull of the submarine. Then, on pumping out the pontoons they came up to the surface, bringing the submarine with them. In this way all danger of damage due to sudden storms was avoided because water under the surface is not disturbed by storms overhead.

(TO BE CONTINUED)

Destroying the Argentine Ant

MR. C. W. MALLY describes, in the *South African Journal of Science* (Vol. XIII, No. 11, July, 1917), a method of destroying that noxious pest the Argentine ant. The plan is to surround the opening of the nest with a cordon of finely powdered corrosive sublimate about half an inch wide. Under some conditions the ants become excited before they actually touch the powder, the result being probably due to the fact that fine particles of the sublimate are floating in the air. When the drug has been sprinkled on the soil at any point, it remains sufficiently virulent to affect the ants for a long time; some spots thus treated after eight or nine months still react on the ants when they wander over them. Heavy rain disperses the sublimate, but light rain simply carries it into the soil, and then, as the moisture evaporates there is a tendency for the corrosive sublimate to be re-deposited on the surface. Foundations of buildings may be protected from ant invasion.—*Nature*.



Here the diver rides to the bottom on a large weight, attached to a hoisting line

Ferro-Concrete Ships—II*

A Review of Some of the Technical Features of Construction

By T. J. Gueritte, Ing.E.C.P., M.Soc.Ing.Civ. (France), Councillor of the French Board of Trade

[Concluded from Scientific American Supplement No. 2209, Page 287, May 4, 1918]

IV.—EASE AND SPEED OF REPAIRS

This question of speed in construction leads us to another important consideration, viz., the ease and speed with which ferro-concrete ships may be repaired. Ferro-concrete has been proved to withstand damage to a remarkable extent. One need only refer briefly to its excellent behavior during the earthquakes, during subsidence of foundations, etc. This is due to the monolithic character of the work and its great cohesion. The following example will give a clear idea of the possibilities of ferro-concrete in that respect. In 1909, a monolithic building was erected from Messrs. Mouchel & Partners' designs at Northwich, a district famous for appalling subsidences due to the extraction of brine from the lower strata. The building, boxlike fashion, rested on 20 foundation piers, but without connection with them, and it was arranged that the piers should be kept under observation, so that if any showed signs of subsidence packing should be inserted and the building jacked up. In December, 1915, signs of subsidence were detected, and a joint inspection was made by the surveyor of the Northwich Salt Compensation Board and the author, when the almost incredible fact was revealed that out of the 20 piers 12 had subsided and parted with the superstructure, the latter remaining supported on eight piers only. Enormous strains must have developed in the portions of the building thus transformed into big cantilevers, but the report stated that "thorough inspection of the whole building, with special attention to mainbeams, secondary beams and ceilings failed to reveal any trace of weakness or strain." Such is the resiliency, the power of accommodation to new circumstances, of ferro-concrete. Again, in 1907 an 8,000-ton steamer crashed into a ferro-concrete jetty in the river Thames. The engineer, Mr. C. S. Meik, M. Inst. C. E., stated at the time that if the jetty had been a timber one, the steamer must have gone right through it. As it was, the only damage was the destruction of a few piles and about 20 square feet of decking. It must be understood that damage to ferro-concrete work is always of a most localized nature. At the time of the great explosion at Silvertown in January, 1917, a steel girder weighing nearly one ton was blown up and fell headlong upon a ferro-concrete wharf some 50 yards away. It went through a panel of the decking, but the hole made was hardly more than 1 foot by 2 feet, the adjoining beams not suffering in the slightest; the damage was therefore insignificant and most easily repaired. This localization of damage, which is extremely important in ship construction, is borne out by observation of the effects of shell fire on ferro-concrete. On the western front a ferro-concrete water tower 52 feet high formed for a long time a convenient observation post for the Germans and a prominent target for our guns. When in March, 1917, the Germans proceeded with their so-called "victorious retirement," they took good care to bring down the tower by dynamiting its legs, the tank proper falling from its full height to the ground. But according to written statements, the shells which had struck the tank merely made circular holes through the sides and bottom, and the fall to the ground caused only local cracks. After small repairs, the tank could be used either on the ground or jacked up gradually to its original position.

Such local damage as may occur in ferro-concrete ships will be most easily repaired, the hole being blocked up by providing a small timber shuttering and filling the hole with new concrete, after having added, if need be, a few strengthening bars. By using a very rich mixture of concrete, the patch will be able to stand the water pressure in a couple of days or even less, and if need be, one may not remove the shuttering before putting to sea again, for further safety. Such a repair may even be carried out under water. Cementing or concreting repairs to quay walls or jetties under water are by no means processes unknown to civil engineers.

In December last the author had the good fortune (if he may put it that way) to inspect a 1,000-ton barge which a couple of days previously had suffered damage during a faulty launching; it had been repaired as explained above, and was then afloat and in excellent condition. Several instances of damage to river or canal barges in use abroad have been recorded, pointing all to the same conclusion, and all investigators seem agreed that repairs to ferro-concrete ships will be quicker and much cheaper than to steel vessels. Alterations to the design in course of erection, or while the ship is in service, are quite easy. The author has witnessed in France a fairly sweeping alteration in the position and arrangement of hatchways and companions in a vessel nearing completion, which confirms this statement.

V.—LASTING QUALITIES OF FERRO-CONCRETE VESSELS

Views on that aspect of the question are difficult to express, for the reason that experience has not yet been obtained regarding their behavior at sea over long periods. Most probably steel shipbuilders found themselves in the same predicament when steel was first put forward as a substitute for timber. Let us also proceed by inference. We know that ferro-concrete on land is a most permanent material, requiring no upkeep, no painting and increasing in strength with age. We know that the same applies to ferro-concrete sea work or tidal work, jetties, quays, etc., when properly designed and carried out. There may have been a few cases (very few indeed in proportion to the number of successful works) in which defects developed. But in those cases the defect can always be traced to causes which do not affect the principle of ferro-concrete, and could have been avoided by taking due care. The author has read practically every attack made upon ferro-concrete and its lasting properties, but up to the present he has not seen one that was vital. Local examples being always of special interest, one may properly refer here to a ferro-concrete jetty built in 1901 at the C. W. S. works, Dunston-on-Tyne, with a rise and fall of tide of 15 feet, and which is in absolutely perfect condition, although it is now submitted to much greater shocks than was anticipated owing to the increased tonnage of vessels accommodated.

We know, further, that ferro-concrete vessels for river or canal or harbor work have stood the test of time very well indeed; comprehensive lists of such vessels have been printed so often lately that it is unnecessary to repeat them.

On the other hand, we know that seacraft are submitted to much more severe strains, and this is where doubt may arise. To overcome the difficulties which confront ferro-concrete seacraft, one must first of all realize them fully, and recognize the inherent drawbacks of the material. It is then comparatively easy to devise means for removing the disabilities. That there will be failures cannot be doubted. Most of them will arise from imperfect understanding of the effect of combined stresses. But the experience already at our disposal is sufficient to show that some of the difficulties encountered can be overcome by more careful designing, and there are good grounds for assuming that the ferro-concrete vessels which it is now proposed to build up to a certain size will have the necessary lasting qualities. The question now arises as to what is the limiting size of ferro-concrete ships, but before trying to give a tentative reply to the query it is necessary to face one of the great defects of ferro-concrete vessels, viz., their weight.

VI.—WEIGHT OF FERRO-CONCRETE VESSELS

It is so obvious that ferro-concrete vessels are heavier than steel ones that there is no need to explain why. The important point is to make a comparison between vessels of the two classes and of same deadweight carrying capacity. The designs of vessels upwards of 1,000 tons deadweight prepared by the author's firm comprise one deck single-screw cargo vessels of 1,000 tons, 2,000 tons, 4,000 tons and 6,000 tons deadweight, and the comparison will be limited to those. It must be stated that the full detailed working plans for the larger units are not quite completed as yet, so that slight alterations in the figures here below given are possible.

In the following tables the figures referring to the steel vessels have been kindly prepared by Mr. R. Cole and Mr. H. Burgess, of Messrs. Sir W. G. Armstrong, Whitworth & Co., Limited, the design of the ferro-concrete vessels has been prepared in collaboration with Mr. T. G. Owens Thurston, of Messrs. Vickers, Limited, and to them the author wishes to tender here his best thanks.

The annexed Table I allows one to compare at a glance the main characteristics of the vessels. From the figures in that table another Table II has been prepared, which gives the factor for converting deadweight carrying capacity into total displacement, both for the steel and the ferro-concrete vessels figuring in Table I.

Table I.—*One-Deck Single-Screw Cargo Steamers.*

Deadweight all told in tons..	1,000		2,000		4,000		6,000	
	Steel.	Ferro-Concrete.	Steel.	Ferro-Concrete.	Steel.	Ferro-Concrete.	Steel.	Ferro-Concrete.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Length between perpendiculars ..	180 0	210 0	220 0	245 0	285 0	305 0	340 0	355 0
Breadth moulded..	29 0	33 6	35 0	38 9	41 6	44 3	45 9	48 0
Depth moulded to upper deck	16 6	16 9	20 0	20 3	25 0	25 3	28 3	28 6
Mean draught	14 9	14 9	17 9	17 9	21 3	21 3	23 3	23 3
Displacement in tons .	1600	2225	2910	3660	5550	6465	8240	9210

Table II.—*Factors for Conversion of Deadweight Carrying Capacity into Total Displacement.*

Deadweight all told in Tons.	1,000	2,000	4,000	6,000
Steel vessels ..	1.600	1.455	1.387	1.373
Ferro-concrete vessels ..	2.225	1.830	1,616	1.535

Table III.—*Excess Displacement of Ferro-Concrete Vessels over Steel Vessels of same Deadweight Carrying Capacity.*

Deadweight all told in Tons.	1,000	2,000	4,000	6,000
Excess per cent.	39	25.8	16.5	11.8

VII.—COST OF FERRO-CONCRETE SHIPS

The saving which can be effected by ferro-concrete in a certain class of vessel is due partly to the saving in steel, partly to the fact that no heavy plant is required for ferro-concrete work, and partly to the fact that the bulk of the labor employed need not be skilled, and is therefore cheaper. But if the last two factors remain the same whatever the size of the vessel, the first is a variable one. To start with it must be stated that the saving in steel is not as great as was wildly claimed at first by superficial designers who had not grasped the difficulties of the problem, a saving of 80 per cent. or even more as has been mentioned occasionally seems quite out of the question. Nevertheless the saving exists, and in some cases exceeds 50 per cent. or 55 per cent. which is not at all negligible. And in that respect it is as well when comparing figures to note that in ferro-concrete there is no waste of steel in the process of construction whereas it seems a recognized fact the weight of steel required for building a steel ship is about 10 per cent. greater than that of the steel which is finally embodied in the structure owing to waste in cuts of plates, angles, rivet holes, etc. As far as stresses go steel is not used very economically for steel ships of small tonnage, but it receives a better utilization when the tonnage grows. By way of illustration, taking as units the stresses per square inch on the upper deck and on the bottom plating respectively for steel cargo vessels of 1,000 tons deadweight, it may be assumed that the stresses in bigger vessels would approximately be greater in the ratio shown in the following Table IV:

Table IV.—*Ratio of Increase of Stress Tons per Square Inch.*

Deadweight in Tons.	1,000	2,000	3,000	4,000	5,000	6,000
On upper deck ..	1	1.18	1.33	1.44	1.54	1.64
Bottom plating .	1	1.22	1.40	1.58	1.75	1.94

It will be seen that steel vessels have to meet the same difficulty as ferro-concrete vessels in the case of small tonnage, viz., a bad utilization of the full strength of the constituent materials. Whereas, however, in

*Paper read at the Northeast Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne, March 12, 1918. From a report in *Engineering*.

the case of ferro-concrete it is the concrete which is badly utilized (as far as its potential strength is concerned), in steel vessels it is the steel. In both cases the drawback disappears when the tonnage increases.

A much better utilization of the steel takes place in ferro-concrete ships of small tonnage, utilization which cannot be improved upon very much when tonnage increases. It would seem that the important saving in steel resulting from the adoption of ferro-concrete for ships of small tonnage remains a fairly constant percentage up to, say, 3,000 tons deadweight, but in the light of present designing that for larger units it would become gradually smaller.

It is most difficult to give an accurate comparison of the prices for steel and ferro-concrete ships. The question is so beclouded by considerations of many kinds that it has been questioned whether the undeniable advantage which ferro-concrete offers today in this respect will remain when normal times return. The author feels unable to give precise indications which actual experience may alone procure. But it seems fair to say that on a pre-war basis one may estimate that the cost of the ferro-concrete hull is about 70 per cent. of the cost of the steel hull of same deadweight carrying capacity in the case of small tonnage, the saving becoming somewhat less important for bigger units. As against this one may set up the fact that the cost of machinery and outfit for concrete vessels is, approximately, 5 per cent. dearer than it is for steel vessels.

Failure in Metals

Its Cause and Diagnosis

By F. Rowlinson

CAUSES of failure in metals may be classed under at least three heads. The first of these, defects due to engineering shortcomings such as faulty design and erection, negligence and corrosion, etc., is strictly within the sphere of the engineer, and as such must be excluded from the scope of this article. Another prolific cause of failure is defects in the material as delivered to the user. For instance, an incapable or ignorant man will often order materials for work for which they are unsuitable; their failure is complained of to the manufacturer. If only to protect himself, it behooves the latter to undertake a thorough examination of the specimens. Careful and systematic chemical analysis on the part of the manufacturer and the user will greatly minimize breakages due to this cause. If the user states his requirements clearly and unmistakably to the maker, the latter will usually make it his business to select metal of composition suitable to the work in hand.

By far the most prolific source of failure in material as delivered by the manufacturer is segregation of constituents, and the presence of blowholes, rolling flaws, etc. Fortunately these are all easily diagnosed. Blowholes and flaws are usually evident on inspection of the fractured surface; if not visible to the naked eye, they can be discerned with the help of a powerful pocket lens. Segregation is made evident by chemical analysis of various parts of the sample, or by such methods as "sulphur prints" or by etching with various reagents. Examination under the low-power microscope is of considerable value in special cases. Thus, for instance, a specimen of steel was found to be "red-short" in working. An examination under the microscope showed that the sulphur was present in reticulated form, forming a network round the grains of iron. This points to excess of sulphur and insufficiency of manganese, since, when manganese is present in quantity sufficient to form manganese sulphide, this separates, not as a network between the grains, but as isolated globular masses. These are by no means as dangerous as the network of sulphide. In the case considered chemical analysis confirmed the conclusion arrived at by the microscopist.

Heat treatment is perhaps one of the least understood and most abused of metallurgical operations. The uncertainty resulting from ignorant and inefficient heat-treatment is so well known that, although much structural steel, for instance, would undoubtedly be improved by intelligent annealing, it is considered safer to trust to luck, and to take the material as it leaves the rolls. With the exception of large and intricate castings and forgings, over which time and money can be spent, more harm than good is done in many cursory attempts at a comparatively little understood process. Heat-treatment must be well done or not done at all—half measures are a fruitful source of failure. To detect such, microscopic analysis for grain size, and a higher power examination for intimate details of structure are usually sufficient. Physical and mechanical tests are also useful, although in some quarters grain size determinations are thought to yield sharper and more decisive evidence. The latter are made upon the polished and etched surface by any of the well-recognized methods, such as the planimeter or "intercept" methods. Both vertical and oblique illumination are used, with a magnification of from 50-100 diameters. Comparison with standard specimens whose history is accurately known is desirable. The determination of constitutional microstructure is more difficult, and is usually carried out at from 400 to (in extreme cases) 1,500 diameters. Long skill and experience are necessary in this branch, and the personal element is all in all.

The third class of failures met with in practice is due to maltreatment of the metal after it has left the hands of the manufacturer. Many of these defects can be traced to excessive cold working, as in punching, bending and shearing operations. The actual abuses out of which the defects arise are legion; their result is usually the same, namely, a local hardness, particularly dangerous under shock. Strains of this character are made evident by mechanical tests, notably in the increase of the elastic limit. Very decisive evidence is obtained from grain size determinations, and where possible comparative data as to grain size before and after cold working are obtained. From them may be formed approximately correct quantitative estimates as to the nature and amount of cold work. Careful consideration of such data will often decide as to whether the grain distortion is due to moderate cold working without further treatment, or excessive cold working followed by annealing as a remedial measure. The investigator must always bear in mind, however, that elongated grains are not necessarily consequent upon cold working, but may be frequently found in cast metal, the elongation depending upon the direction and intensity of cooling.

Other frequent failures can be traced to unfair treatment of the metal in smithing and similar operations, due to "slackness" and forced output; to the employment of inexperienced workmen; and often to entrusting materials of unfamiliar composition to workmen accustomed to work upon special and unvarying brands. Evidence of all such maltreatment is yielded by micrographical and physical tests.

From the foregoing summary of the chief sources of failure and the means employed to detect them from the fractured metal, it will be seen that chemical, physical, mechanical and microscopical methods are all made use of. Each method is usually of small importance in itself; it is by correlating the evidence yielded by different methods that a definite conclusion is arrived at, and to do this successfully needs a considerable measure of skill and intelligence of a detective nature. We will take a typical example from practice. A section of rail has failed through no apparent cause. Two pieces, A and B, each containing a fractured surface, are cut off and taken to the laboratories. Piece A goes first to the chemical department. Of the chemical tests analysis is, of course, the most obvious and most usually employed. Analyses from various parts of the sample give an average composition and also determine any variation in composition throughout the mass. Should analysis set up any suspicion of segregation an interesting chemical method of detecting it may be applied to piece B. This is the "sulphur-point" method. It has been observed that the segregation of sulphur in steel occurs with the general segregation of the other impurities. The specimen to be examined is given a smooth surface, and upon this is plastered a piece of ordinary photographic paper, previously moistened with dilute sulphuric acid. The latter acts upon the sulphur compounds in the steel, liberating sulphuretted hydrogen, which attacks the silver of the photographic paper, giving a brown or black stain wherever segregation has occurred.

The further treatment of the specimens depends upon the chemical tests. If these prove satisfactory showing the cause of failure to lie elsewhere, then specimen B is taken to the physical laboratory, and the requisite test pieces are sawn out. The test most usually applied here is the tensile test. It is preferable that the testing machine be fitted with an autographic recorder, since the diagram obtained gives not only the maximum stress, elongation of the specimen, and breaking stress, but the elastic limit and yield point. The form of the curve, too, gives very definite information as to the character of the metal, heat treatment, etc. The nature of any other mechanical tests to be applied is decided by the uses for which the metal is intended. In the case of the rail we have considered the tensile test would probably be considered sufficient, but for other kinds of metal many other tests are imposed. One of the most frequent of these is to alternate bending test. The sample to be tried is placed in a grip and repeatedly bent forward and backward in very rapid alternations, until fracture occurs. In the Arnold machine the alternations are ten per second, and an automatic counter is fitted, which is cut out as fracture occurs. A more recent machine by Sankey not only records the number of alternations but also the effort required to produce each bend. Hardness, another property very often determined, presents some difficulty. This is due to the unfortunate fact that there are so many similar, but slightly differing, conceptions of what exactly constitutes hardness. The Brinell test determines the resistance to penetration of the specimen by a hardened steel ball, pressed upon its surface by a definite load. From the diameter of the hole left the depth of penetration is calculated, and the hardness number is then read off from a table. Another test consists in making a standard scratch upon the surface of the specimen with a loaded diamond point. The load in grammes required to produce the scratch is taken as a measure of the hardness. One of the most used methods depends upon the height of rebound of a hard steel ball which is allowed to drop a definite distance upon the test piece. The whole subject of hardness testing is as yet chaotic; so many of the tests proposed are dependent either upon some other property of the metal under test, as elasticity, etc., or are limited by the "personal equation." Notwithstanding this, any one method in itself will give comparative results, which are all that is required in the investigation of failures. Torsional or twisting stresses, and suddenly applied (impact) tests are of value where the metal has failed under such treatment.

Whilst piece B has been undergoing mechanical tests, specimen A has been examined in the "micro"-laboratory. The macroscopic and microscopic examinations usually necessary are limited to grain size determinations and the detection of mechanical defects. These are both done under low powers, and for the latter no grinding is permitted, as it would remove "ghost" cracks, and other indications which are not deep-seated. Pickling in dilute acid develops any flaws, blowholes, etc., and these may then be examined under a very low power. Where heat-treatment (or mal-treatment) is supposed to be the cause of failure, it becomes necessary to conduct an investigation into the intimate micro-structure of the test piece. This is rather laborious, requiring much skill in grinding and polishing the specimen, and particularly in recognizing the structure. All metals have a structure similar to that of igneous rock, and the constituents of the metals obey similar laws. But before these constituents can be recognized, the surface of the metal must be brought into a condition suitable for examination under the microscope. It is evident, of course, that the specimens cannot be viewed by transmitted light, since they are opaque. Hence arrangements of the microscope have to be made so that the lighting is by reflection, either vertical or oblique. A small piece of the metal under examination is cut out with a hack saw, in size about ½ inch diameter by ⅛ inch thick. One side of this is ground flat, and then filed with a "dead-smooth" file. It is then rubbed upon graded emery papers, each successive operation removing the scratches left by the previous one. Finally the piece is polished upon a revolving pad coated with kidskin, and the finest rouge procurable is used. The next operation is etching. This consists of developing the structure by immersing the metal in some suitable reagent which shall eat away certain constituents, leaving others in high relief. The polished and etched specimen is then examined under the microscope, and should anything worthy of record be noticed, a permanent photomicrograph is taken.

When all the data obtained in the various testing departments has been collected, and as much as is available of the previous history of the sample has been looked up, the whole of the evidence is put before a man specially skilled in this branch. By carefully correlating the facts before him, he is then able to diagnose with unfailing accuracy the cause of failure.

History in Tools*

An Important Factor in Civilization That Has Been Neglected

By W. M. Flinders Petrie, F.R.S., Professor of Egyptology, London University

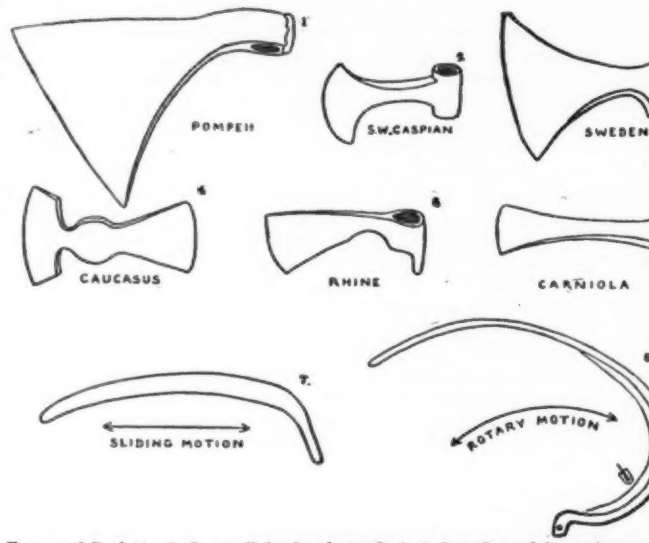
In modern teaching, political history has overshadowed all other aspects of man, and the general history of civilization has not yet received recognition. It matters nothing whether Aristotle, Euclid, Newton or Pasteur, lived under a republic or a despotism; but it is of the first importance in history to know the influence of such thinkers and discoverers. The movement of man's mind in ideas, knowledge, and abilities should be one of the principal and most stimulating subjects in education. This would not be a materialistic limitation, and one side of it has been admirably written already in Lecky's *History of Morals*.

Among the activities of man, the development of his means of work must certainly be considered. But while there are many books on offence and defence, arms and armor, there is none that traces the history of the mechanical aids. Thousands of writers have described the sculptures of the Parthenon, not one has described the means used in performing that work. It is a mystery to us how fluted columns with an entasis could be produced, true to a hundredth of an inch, in the diameters between the deep groovings.

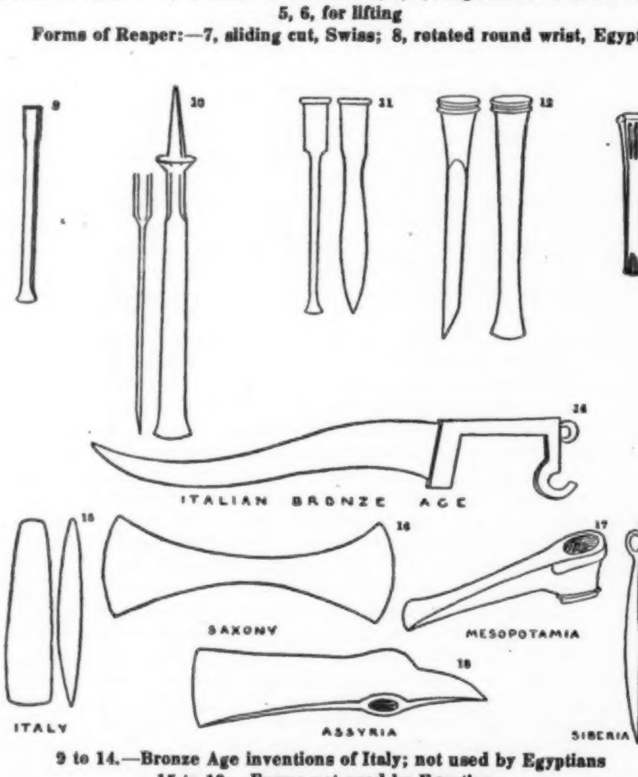
In taking up the neglected history of tools,[1] the nature of the materials used is the first view to consider. After the stone ages, the order of metals,—bronze and then iron,—is tolerably well known. Of late years an earlier age of copper has been noticed in several countries; and this again may be divided into an age of native copper and an age of smelted copper. The use of copper in the American hemisphere was entirely limited to native copper, never smelted; in fact it was the stone age, including a malleable stone. Native copper is also found in various places in Europe and Asia, and it seems only reasonable to suppose that it would be worked before smelting was discovered. What points to this is the pillowy form of tools in the earliest metal age of most countries. This form could not be cast except in closed moulds, but it would be the most natural for hammered native metal. The earliest stage of casting was the mere limiting of out-poured metal in an open mould, and hence flat castings, such as are found in Egypt, and such as appears in other countries after the hammered forms. The order of use of metallic materials, then, seems to be native copper, smelted copper, bronze, iron, steel, and brass. Copper may be hardened by small impurities and much hammering, until it is equal to any bronze; the main purpose in using bronze was probably to facilitate casting, especially for closed moulds. The *cire perdue* process also needed bronze, and that was a favorite mode of work, from early Egypt to early Britain. In both those lands the metal was run to an astonishing thinness, often only a fiftieth of an inch, a mere film over the sand-core.

When the variations of the forms of tools in different countries are compared, much is seen to depend upon climate. In the north (figs. 3, 4) sockets are much larger and deeper than in the south (figs. 1, 2); this is due to the softer and more stringy nature of northern woods, which would be bruised and crushed in the leverage of a small socket. Neither oak nor ash nor beech could compare with the Syrian *shum* for resisting a wrench. The varying purposes also led to very different forms; the slight socket and large blade for a fighting axe, when the blade was not gripped in the cleavage; the splitting axe with a long socket to enable a side-wrench to be given; the cleaving axe with a long back to the socket (figs. 5, 6) to aid in a lifting pull to get it out of the wood. In the agricultural tools there are clear distinctions between the scythe or sickle worked with a sawing motion from the hand at the end of the blade (fig. 7), or the reaping sickle with a circular arc around the wrist which rotates it (fig. 8), or the pruning-hook to top off high vine-sprays in the south (fig. 46), or the bill-hook to cut copse-wood in the north. The different kind of motion must be considered before we can understand the varying use of each tool. In weapons, similarly, the width of spear or arrow-head is conditioned by the defence. On bare bodies wide cutting blades are the most effective, to attack clothed bodies a narrower blade is needed, and for piercing armor of leather or metal a mere spike is required.

These forms which result from the necessities of use, and the guidance of utility, may very probably be evolved in many different centres quite independently. We know, in modern times, the Patent Office shows how often a simple thing may be reinvented. The case is different, however, when we look at artistic style; in that, each race or country has its own characteristics which cling to it for ages, and are seldom adopted by others. When a design recurs we can generally trace its descent, sometimes through thousands of years. Sometimes principles of form also have an astonishing persistence. The northern and Syrian peoples used flanged edges to stiffen tools, the Egyptian and most Mediterranean peoples would have none of them. The European and Asiatic used socket-holes, the Egyptian always rejected them. The European cast in flat moulds, and used punched ornament; the Asiatic cast in closed moulds, and used cast relief ornament. The Asiatic and East European used re-curved outlines, the European and Egyptian used straight or simply curved outlines. In all these respects we see a fundamental artistic difference between races.



Forms of Socket.—1, 2, small for hard wood; 3, 4, lengthened for softer wood; 5, 6, for lifting
Forms of Reaper:—7, sliding cut, Swiss; 8, rotated round wrist, Egypt



9 to 14.—Bronze Age inventions of Italy; not used by Egyptians
15 to 19.—Forms not used by Egyptians

Another curious aspect of the subject is the worship or reverence given to weapons. Spears were kept in the temples of Italy as means of divination, and immense ceremonial spear-heads are known from early Mesopotamia, Italy, Sweden, Britain and China. The scimetar was adored in Scythia, and the Quadi adored their swords as deities. The driving of a nail into the temple of Jupiter in Rome was the means of averting pestilence. The double axe was a usual tool, and also a sacred form; ceremonial copies, which could not be hafted (fig. 16) were made in various northern centres, apparently as standard weights.

Several stages of inventive activity may be discovered, when a great outburst of new types appears. The most prolific period seems to have been in the later bronze ages, about 900 B. C. The most perfect forms of bronze chisels were then devised (figs. 9 to 13), both tang and socket chisels, wide chisels, deep mortise chisels, saws with a uniform rake to the teeth to cut in one direction, great knives of a flamboyant form (fig. 14) with double curves,—all due to north Italian genius. About the same time, or a little later, the Chalybes on the Assyrian side were developing iron and steel tools on modern lines, socket and tang chisels, saws, rasps, and the early stages of files and centre-bits. These were in use about 700 B. C. It is also noticeable how a great wave of ethical ideas appears in that age in Judæa, Greece and Egypt; it seems to have been a potent stage of thought in many branches.

Some tools which have been, and still are, very usual in other lands, are little known in the West. The adze had a very long career, from the early prehistoric age of Egypt, and is still the common tool of the East. It is often now confused with the axe, under the general name of celt; but it is essentially different, being unsymmetrical in side view, and used across the plane of motion. One common form of it, from about 1500 to 400 B. C., has scarcely been noticed hitherto; it has two projections on the side-edge to hold up the lashing which attached it to the handle. It is strange to see how a tool which was commonly used in many countries for a thousand years, has now disappeared from life as totally as the mammoth.

It is too often supposed that because some thousands of years have passed in the history of a tool, therefore we must now be in possession of far better forms than those of past ages. This is true in many cases, but by no means always. The forms of the chisel were perfected 2,500 years ago; and the beauty of work in the bronze age chisels (fig. 10) with perfectly even blades, dished octagonal flanges to the tang, or square sockets ribbed on the outside for strength (fig. 13), has never been exceeded. In other tools there has been an actual loss of good design. The Egyptian form of the Roman shears has one leg detachable for sharpening (fig. 36); it was held in place by two slots engaging T-shaped pins, it could be detached in a second, and yet was quite firm. Such a facility for sharpening is a great advantage, but the form has entirely disappeared. Another Egyptian form was the iron sickle (fig. 8), with a trough groove to hold a strip of steel teeth; this was adapted from the old Egyptian wooden sickle with flint saws inserted, and when steel was valuable it was a great advantage, yet it entirely died out from use. The use of saws and crown drills with fixed teeth of corrundum or gem stones, for cutting quartz rocks, was the regular system of work in Egypt 6,000 years ago, and in Greece 4,000 years ago. The cores produced were so perfect and clean-cut that, as

*From *Science Progress*.

[1]A first step in historical treatment I have attempted, in a catalogue comparing the tools of Egypt with those of other lands, *Tools and Weapons*, with 3,000 figures.

Sir Benjamin Baker said, any engineer would be proud to turn out such good work with the best diamond drills. The saws were over eight feet long, sawing blocks of granite 7½ feet long.

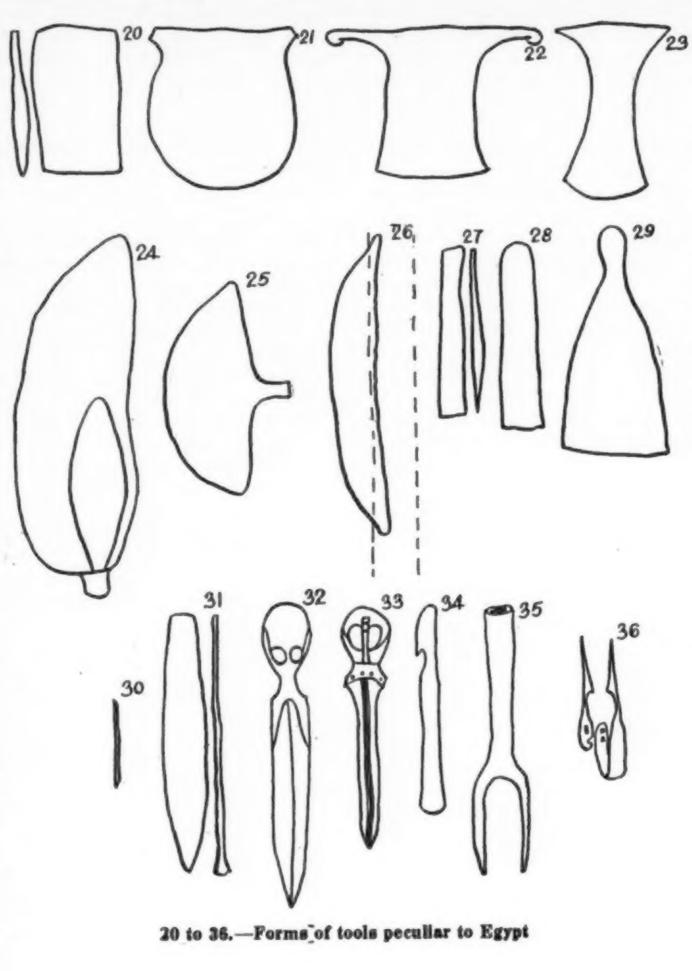
This splendid work was quite forgotten, the Roman had no such grand tools, and some thousands of years passed before such means were reinvented fifty years ago.

In other cases we can trace the gradual evolution of a tool down to the present day. The carpenter's saw was at first merely a blade roughly hacked on the edge; by 4,500 B. C. it had regular teeth, sloping equally both ways; by 900 B. C. the Italian gave a rake to the teeth to make them really cut in one direction, instead of merely scraping as before. No ancient saw, however, had a kerf, cutting a wider slit than the thickness of the blade; we do not know when that was invented in the Middle Ages. The Egyptian used a push-saw as the earliest form; the pull-saw was the only one in the West and the Roman world; the push-saw came back into use in the last few centuries, though the pull-saw in a frame is still universal in the East. The world did without shears for many ages, cloth being cut with a rounded-blade knife (fig. 34). About 400 B. C. the mechanical genius of Italy invented the shears, which in two or three centuries more were fitted to the fingers, and thus started the scissors. The snuffers in Exodus is a mistranslation; the early tools for trimming a lamp were a small knife and pair of tweezers to trim the wick, and a point to part the strands.

In some cases it is curious to see how long men remained on the brink of an invention. Copper wire was made by cutting and hammering, from 5,500 B. C., yet the drawing of wire remained unknown for 6,000 years or more. When the first drawn wire was made is not yet fixed, but it seems to have been unknown to the Romans. Thick beaten wire was made into chain with round links as far back as the second dynasty, 5,200 B. C.; and links doubled up, and looped through each other, appear in the sixth dynasty, 4,200 B. C. Yet chains were not commonly used till much later. The Gauls excelled in such work, as they used chain cables and rigging in place of rope, to resist the Atlantic gales. The screw was a Greek invention, and greatly used by the Romans as a means of motion. Then centuries passed before the nut and screw, for fastening, was invented; and again centuries before the screw used to fasten wood, which first appears less than two hundred years ago.

The light that the distribution of tools throws on the status of ancient civilization is most valuable historically. Not only does the using of certain tools show a level of work and ability, but the resistance to the adoption of forms known elsewhere shows that there was a sufficient ability already in a country. In the present day the forms of common tools differ in various parts of Europe, because each country has a civilization strong enough to carry on without copying another country. A large improvement in one country is the only condition on which other countries will borrow from it, and only then if the changes will suit other conditions. When we find that countries, known to have been anciently in connection, each steadily resisted various forms of tools used by the other, we have good evidence that each civilization was on such a level that it could supply all its wants without great benefit by imitating another. This form of evidence gives some insight into dark ages, of which but little detailed knowledge is preserved; it suffices to show whether countries were far below one another, or on such an equality of work that each was independent.

In Egypt there were many forms of tools and weapons, which were then the standard types, and yet these are never found in other lands. The earliest axe (fig. 20) is a plain square form, from about 6,000-5,000 B. C. Then a round axe (fig. 21) was adopted till nearly 3,000 B. C. After that wider lugs were developed to enable it to be firmly bound on to a handle (fig. 22); and this was made in a lighter and longer form as a battle-axe (fig. 23) used mainly about 1,500 B. C. None of these forms are found in other countries, yet had the lands around Egypt been much behind in their axe forms, they would naturally have been influenced by Egyptian types, as there was trade intercourse during all these periods. The only adoption of such forms was due to entirely independent reinvention of the axe with lugs in South America, without any intermediate example. The form is a natural one to adopt in hammered copper, for getting a firm attachment to the handle.



30 to 36.—Forms of tools peculiar to Egypt

Other adaptations of the axe were the large blade of curved outline on the end of a pole (fig. 24), the half-round halberd (fig. 25), and the long edge set in a stout baton (fig. 26) for a cutting blow. All of these were common in Egypt, but never spread elsewhere.

The adze in Egypt was at first a straight long blade of copper with parallel sides (fig. 27). Later it developed a rounded head-end (fig. 28), with contracted neck (fig. 29), to aid in binding it on a handle. Neither of these was copied in any other country.

The chisel was at first sharp at both ends, and held by the middle (fig. 30). Later there is a deep mortising chisel with an equal curve of each face (fig. 31). Neither of these Egyptian forms appears anywhere else.

The dagger, from prehistoric times onward in Egypt, had a crescent handle held in the palm of the hand (fig. 32), so as to use the weight of the arm end-on for a thrust; whereas the European dagger was always held as a knife, across the hand. The Egyptian ornament was by parallel ribs along the axis (fig. 33); in all other countries the ornament is by lines parallel to sloping edges. Some forms are entirely restricted to Egypt, as the cutting-out knife (fig. 34) with a curved blade for cutting linen, the forked spear-butt (fig. 35), and, in Roman times, the shears with detachable leg (fig. 36), and the sickle with replaceable teeth (fig. 8).

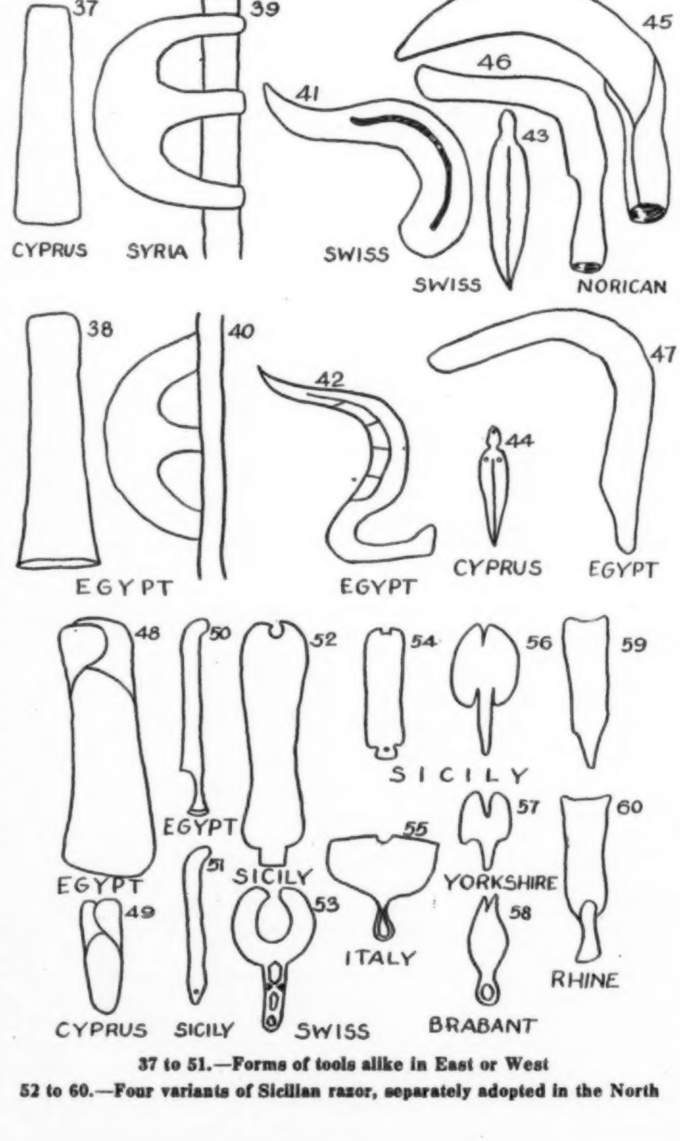
Here, then, are seventeen tools and weapons, mostly of general importance and use in Egypt, which were none of them required by the neighboring lands, where there must have been some useful equivalents.

The converse is equally true; many forms were used around Egypt which never were adopted there. In Cyprus and other lands the earliest axes are of a pillowy form (fig. 15), with bulging faces. In Europe the double axe (fig. 16) was not only a tool and a weapon, but also a sacred symbol and a standard weight. In Mesopotamia the sloping socketed axe was usual (fig. 17), in Assyria the pickaxe (fig. 18). Not one of these was made by any Egyptian, and only two such were rarely brought in by Greeks in late times.

The principle of sockets for handles was well developed in Italy and spread elsewhere, for axes, hammers, and chisels, yet no Egyptian would make a socketed tool, and the only ones in Egypt were brought in by Greeks. The use of hammered sides to a blade, to form a flange for stiffening it, was of early date in Syria, and general in the north. Yet it is rare, and probably foreign, in Egypt, and unknown in the Mediterranean. The girdle knife (fig. 19) is common in the West and in Asia; the flamboyant-blade hunting-knife (fig. 14) was usual in Italy, and spread into the north; the sword was the staple weapon in the North. Yet none of these were adopted by Egypt, and very few swords have been found there, nearly all foreign. In all these cases Egypt did not require a loan from the other lands.

The sharp separation between countries endured for thousands of years, while they were trading in food, materials, and manufacture continually. We can only conclude that each country already had, in these respects, what best suited it.

We now turn to the other historical point



37 to 51.—Forms of tools alike in East or West

52 to 60.—Four variants of Sicilian razor, separately adopted in the North

of view, the forms which are widely spread, because they were required. In Egypt at about 5,500 B. C. there suddenly appeared a very large wide-splayed adze (fig. 38), different from all that came before or developed later. The same large splayed adze (fig. 37) appears in Cyprus; it evidently came from there to Egypt, or both lands drew on a common source elsewhere. About 4,200 B. C. the axe with two large scollops in the back edge (fig. 40), leaving three points of attachment, suddenly appears in Egypt; a thousand years later it is far more advanced in Syria (fig. 39) than in Egypt, and it probably originated there, and spread also to Greece. About 3,000 B. C. a very strange drawing of a sickle appears in Egypt (fig. 42) unlike any other there; this is closely like a Swiss form (fig. 41). At the same time small daggers with notched tangs appear both in Switzerland (fig. 43) and in Cyprus (fig. 44). Here are links from the European copper age to the East. The same line of connection appears later, about 1,200 B. C., when the pruning-hook (figs. 45, 46) from Noricum (the modern mines of Styria) appears in Egypt (fig. 47); the rhombic arrow-head of Greece and Italy is found also in Egypt, the bronze hoe of Cyprus (fig. 49) and Egypt (fig. 48) spread northward in the Iron Age, and the European sword was rarely seen in Egypt.

An interesting confirmation of history is seen in the knives with straight parallel blades and turned-over ends. These are characteristic of the Siculi in Sicily (fig. 51), and just at the time when the Shakal people were attacking Egypt the same knife (fig. 50) is figured in an Egyptian tomb; and a specimen also has been found. This proves the connection between the Siculi and Egypt at the time.

A curious evidence of different trade routes is given by the razor. An unusual form in Sicily has a concave hollow or notch in the end (figs. 52, 54) which was reduced to a mere split (fig. 56), or a slight hollow (fig. 59). The notch form travelled into Italy (fig. 55), by the simple way across the strait. The concave hollow widened as a crescent travelled up to Switzerland (fig. 53) and Germany (fig. 60), probably by the Adriatic. The split form (fig. 56), travelled to Flanders (fig. 58) and England (fig. 57), probably by the Rhone. Here four different modifications branch from a type, and are carried by different routes to distant lands.

The triangular arrow-head is believed to have been started in South Russia. Thence it spread over Central Europe and Central Asia, and was taken by the Scythian migration into Syria about 600 B. C., and hence into Egypt.

Thus the spread of forms throughout the ancient world illustrates the movements of trade and of warfare, while the isolation of various types at the same time shows how efficient and self-supporting the ancient civilizations were in most requirements. The history of tools has yet to be studied by a far more complete collection of material, above all of specimens exactly dated from scientific excavations. It will certainly be, in the future, an important aid in tracing the growth and decay of civilizations, the natural history of man.

The Merchant Ship of the Future*

Problems of the Design and Construction of Merchant Ships

By W. S. Abell, M.Eng., Member of Council

The shipbuilding industry of the United Kingdom passed through at the outbreak of war, a difficult period of acute competition. The demands for new ships until 1911 were below the capacity of the constructive establishments, and the period of 1913-14 witnessed the greatest output this country has ever attained. It is probable that if the war had not intervened the demand for merchant ships would have again fallen off, and that the shipbuilding world would have experienced another phase of rather acute depression.

It is considered that such competition had resulted in a close study of shipbuilding methods and processes, and that as far as the production of ships *qua* ships was concerned, the United Kingdom as a whole was capable of producing them in a most economical manner. Every effort appears to have been made to reduce the weight of material, and in some directions advances had been made in obtaining increased output of labor.

The rules of the Registration Societies imposed a limit upon reduction of weight, and beyond this the only saving possible involved considerations of redistribution of structural material. In general such redistribution required increased labor for fashionment and erection, so that once more a balance was reached between what may be termed the demands on labor and the limitations of material.

Although it is not suggested that further saving is impossible in respect of labor and material for ship construction of the future, yet it is particularly true that in pre-war days the only feature of importance which was closely and scientifically investigated was the question of the resistance and propulsion of ships as affected by the form of the vessel and by the performance of propellers.

Without detailing the various factors which dominate the post-war position, it is evident to all connected with the shipping and shipbuilding industries that the British Empire will have to make strenuous efforts to regain its pre-war maritime supremacy, in view of the disturbance of that position brought about by the present war. And not only is this the case, but the shortage of world tonnage will also require material and labor for shipbuilding to be employed to the greatest advantage.

2. Consequently it is imperatively necessary to enlarge the field of vision and research in order to include every phase of shipping, whether shipowning or ship production. For this purpose, it appears that in this matter of research much closer co-operation is required in the future between all branches of the industry, between the underwriter, the shipowner, the shipbuilder and the marine engineer. It is to the interest of all these parties that the work of marine transportation shall be carried on with safety and efficiency; consequently it is to the interest of all those concerned in the maintenance of the sea power of the British Empire to stimulate and to provide financial assistance for broad schemes of research on shipping questions.

3. In order to realize the value of any particular phase of research, it is necessary to have a touchstone which will indicate the effect of an investigation on the general shipping position. For that purpose it seems necessary to lay down some definition of the function of a ship.

The most successful vessel is that which obtains the greatest power of transportation at minimum cost. Power of transportation may be defined as the quantity carried per unit of time. It is not sufficient for a vessel to carry a certain deadweight alone, but it is necessary that such weight be transported at a given speed, and that the relation of capacity to deadweight be such as to utilize the maximum draught which the dimensions and strength of the vessel permit.

The cost of operation depends on: (*a*) First cost; (*b*) maintenance; (*c*) seaworthiness and safety; (*d*) number and nature of crew; (*e*) fuel; (*f*) speed; (*g*) time spent in port. These factors are to some extent closely related, and the realization of a proper balance between them depends largely on the problem set by the shipowner to the shipbuilder. It may, for example, be good policy to accept a low first cost and subsequently to dispose of a vessel at a period when the cost of maintenance exceeds a certain percentage. The demands of the shipowner may embrace deadweight and cubic capacity, speed, and tonnage. It is then the part of of the shipbuilder in open competition to produce the lowest first cost and disregard any factors other than those directly specified. The builder cannot, however, ignore the fact that if quotations are equal, preference will be given to the vessel which makes least demands on labor and material for operation. The shipowner has the greatest experience of these factors, and consequently it is in directions such as these that he should give encouragement to research.

4. This discussion of the economics of ship operation brings out certain features which, in view of the needs of the future, require close study. The questions of labor and material required for operation involving economical production of power are mainly for the consideration of the marine engineer. The relation of power to speed has received, and no doubt will continue to receive, the attention it deserves. It may now be of interest to proceed with a more detailed account of the directions in which future research should be encouraged, deferring until later questions relating to economy of production.

A. ECONOMY OF SHIP OPERATIONS.

5. *Resistance of Ships.*—A large amount of data has been accumulated as the result of the form experiments made in the various experimental tanks of this country, as well as elsewhere, notably in the United States. As a consequence, it is possible now to obtain a fairly close approximation to the plain form required for a given displacement, length and speed. Such results are of great value when used on comparable forms, but much work still remains to be done to complete the knowledge of the various corrections to be applied to the results of model experiments in order to obtain the data for the full-size vessels. There is no doubt that the resistance of the model as regards wave-making can be very accurately measured, and there is also very little doubt, if any, that the wave-making resistance of the full-size ship is accurately given by a scale correction of the model results.

It is to be observed, however, that in the large majority of merchant vessels the wave-making resistance is only some 20 per cent. of the total resistance, the remainder being due to skin friction and eddy-making. The frictional resistance requires to be estimated, and here the basis of calculation is determined by experiments which have been made mainly on planks of small area and of lengths not exceeding 50 ft. The extension of such results to the ordinary merchant ship of, say, 400 ft. in length, and particularly to the large fast liner of, say, 800 ft. in length, is largely a matter of conjecture. Moreover, the nature of the surface has a large effect on the calculation. The general trend of such results as exist indicate that with a paint or varnish surface the frictional resistance per unit area at given speed diminishes with the length. If the estimates of power are to be more closely approximated to in future, it is essential that some large-scale experiments on frictional resistance of full-size vessels should be carried out in order to obtain some basis to correct the frictional calculations obtained from model experiments.

6. *Power Required at Sea.*—The usual tank experiments provide an estimate for power in terms of speed, under what is termed "still-water conditions." It is becoming increasingly necessary for cargo vessels employed on liner routes to be very reliable in timekeeping between port and port, and to be largely independent of the variation of weather conditions. This can only be obtained by providing a reserve of power beyond that necessary for still-water propulsion, and the estimate of such margin is largely a matter of experience. It is not an easy task to obtain even an approximation to the loss of speed brought about in rough weather, and it is still largely a matter of opinion whether the form which is most suitable for speed in smooth water is the best form for speed-keeping under average conditions. In order to obtain data, it would be necessary to run model experiments, to have a fully loaded measured mile trial of the vessel, and to analyze to some extent (making allowance for weather conditions) the performances of vessels on service. There do not appear to be great difficulties in the way of such procedure, provided shipowners will co-operate on a generous scale.

7. *Resistance of Appendages.*—Model experiments are determined for a "naked" ship; that is, certain appendages are omitted, such as shaft brackets, shaft bossings, rudder posts and rudders, and bilge keels. It has been found that on the small scale of the model, the addition of such appendages tends to increase resistance out of proportion to the effect produced in the full-size vessel. There is no doubt, however, that the resistance of these appendages is of importance, not only as regards form, but also as regards performance of propellers. It follows, therefore, that experiments on a large scale would be of assistance, and might conceivably form part of the proposed friction experiments on a full-size vessel.

8. *Screw Propellers.*—Although much attention has been given in many directions to model experiments with screw propellers, yet, in view of the enormous complexity surrounding the problem, it is still possible for an expert to design a bad propeller. The sensitive-

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ness of the screw to any slight variations in proportions is well known, and consequently, in view of the difficulties of determining the velocity of the water in the vicinity of the propeller, which in general is merely guessed at, it is apparent that an extension of knowledge would be of benefit to all concerned. Here, again, the advantage of some methodical series of large-scale experiments co-ordinated with complementary experiments in a tank will be of service, and will further help to establish a proper relation between the performance of a model and the actual vessel. There are many well-known troubles with the propeller which need not be particularized here, but some attention may perhaps be drawn to the desirability of arranging the form and shape of blades so as to reduce vibration to a minimum. It will also be helpful if shipowners would, as occasion offers, carry out measured mile trials of fully-loaded vessels, and have the results carefully analyzed. Care would have to be taken to obtain accurate measurements of pitch, diameter and area, and form of blades. Moreover, when the trial data were available, the information could be supplemented by careful logs of sea performance under different weather conditions.

9. It is now opportune to discuss certain points for research, which although having features in common, yet perhaps may be differentiated into two main classes, viz., factors of design and questions underlying economy of production of vessels.

Factors of design might include questions relating to: (*a*) Seaworthiness; (*b*) safety, involving (1) stability, (2) subdivision; (*c*) time spent in port; (*d*) relation of deadweight to capacity.

10. *Seaworthiness.*—Questions of seaworthiness and sea-kindliness have been discussed on many occasions with advantage. The factors which tend to facilitate good time-keeping are largely height of platform forward, coupled with sufficient reserve of buoyancy. The proper relation of breadth of vessel to depth to the upper or bridge deck is also of more importance than is commonly accepted. It is true that a moderate breadth favors easy rolling, but, on the other hand, it may prevent reasonable economy in working the vessel in average trades by requiring an undue amount of ballast. It has been said that there are more fashions in ships than in feminine attire; be that as it may, there is a certain cycle in operation which recurs at intervals of some twenty-five to thirty years. There was a tendency just previous to the war to revert to narrow and deep ships, such as were shown to be dangerous some thirty years ago. The tendency was not, perhaps, very marked, yet, owing to the adoption of the shelter-deck type and the subsequent addition thereto—found necessary by sea experience—of forecastle, bridge and poop, the narrow and deep type was being slowly approached. Recent investigations made by the Loadline Committee have shown that the ordinary three-island vessel with long bridge and two short wells with good proportions and with the ordinary freeboard is probably the most seaworthy type of those at present in vogue.

11. *Stability.*—Stability at sea, although perhaps the want of it is fortunately not often experienced, is of great importance. Present knowledge of the subject is confined to statical calculations; estimates of the arm of righting couple and the angle of vanishing stability for the ordinary merchant ship are seldom made. The question of initial stability and the determination of the metacentric height are generally not considered, or at best only evaluated in an empirical manner, and very few attempts have been made to deal with the general question of the stability of a vessel in a seaway in terms of dimensions.

A ship among waves and exposed to wind pressure is subject to displacement from the position of equilibrium by reason of the energy transmitted from the wave and wind systems. This energy is absorbed in two directions: (1) by the resistance of the form and keels to rolling, and (2) by the righting couple due to the inclination of the vessel. It is possible to calculate approximately, or to deduce from model experiments, the rolling resistance in still water, and it should also not be difficult to approximate experimentally to the same factor when a model is exposed to a regular system of waves. The righting couple is calculable both for still water and approximately so for a regular system of waves. Consequently it seems possible to deduce from experience the curves of stability which should be provided for a vessel of given dimensions when exposed to heavy weather. Expressed generally, the quantity to be determined is the work required to capsize the vessel, and this quantity is the difference between the energy transmitted by the wave and wind systems and the resistance to rolling among waves.

Detailed reports of the experience of vessels in bad weather would give the basis of such determinations, care being taken to obtain the relative speed, magnitude and direction of the wave and wind systems, and the speed, displacement, position of centre of gravity and rolling of the vessel, which factors are not difficult to obtain with sufficient accuracy.

12. *Watertight Subdivision.*—This question received much consideration in pre-war days, and rules for the subdivision of passenger vessels were drawn up in this country, although, owing to war conditions, the introduction of these regulations has been deferred for a time. Experience of submarine warfare appears to show that some further consideration is required, more particularly in regard to the relation between nature and extent of damage and amount of subdivision. For example, if the expected damage be mainly vertical in extent, then it appears reasonable to adopt a standard of subdivision which involves a fractional number of compartments open to sea. But when damage extends for a considerable distance longitudinally the chances of loss of a bulkhead are largely increased, and in this case it appears necessary to conform to an integral number of floodable compartments. In other words, while it may be reasonable in the one case to aim at a standard of sub-division equivalent to, say, 1 1-3 compartments flooded, in the second case the choice would lie between either a one-compartment or a two-compartment standard. The difficulties of the present modes of calculation have been already pointed out in several directions, and it certainly appears desirable, in view of experience, to attempt to find a modified system of rules which would be as easy of application as possible, having regard to the necessities of the case.

13. *Time Spent in Port.*—It is not generally recognized that the great majority of vessels spend perhaps half their existence in port. During this period the vessel is unproductive—*i.e.*, is piling up charges and is not earning freights. Even in long voyages from this country to the most distant parts it is not uncommon to find that only 60 per cent. of the time is passed at sea. For economical transportation it appears vitally necessary to study every method which will reduce this drawback, not only with reference to ports, harbors and railway facilities, but also with reference to the vessel herself. It appears that this factor is one of supreme importance in design and has not received the attention it has deserved. For example, there must be an economic relation between the length, breadth and depth of holds. A narrow, deep hold, except perhaps for bulk discharge, must obviously be more difficult to work than a broad and shallow space. Again, there will be a close economic relation between size of hatch and area of hold space and between the ratio of 'tween-deck space to hold volume. Great attention has been paid to the discharging appliances, but there is no doubt that even here a close study of the economic requirements will result in savings in many directions.

14. *The Relation of Deadweight to Cubic Capacity.*—It is admittedly a difficult matter to determine the proper relation between the deadweight carried and the space available for stowage in the case of the cargo tramp. But as owners work more or less through fixed agencies it will happen that after a time conditions somewhat approximate to stability, and within limits a ratio can and should be obtained. It is extremely desirable that a vessel should carry as much weight as possible, but the determining factor in the tonnage of this country in the past has been the imports of raw material, which are relatively bulky. Consequently on the supposition that pre-war conditions are maintained—and they must be, since the sea power of this country is largely determined by a thriving industry in the United Kingdom—the aim must be capacity rather than deadweight. The proper relation for general purposes of these two quantities is therefore an important question for broad research. With given dimensions, capacity can only be gained by reducing deadweight and by reducing the machinery space.

B. ECONOMY OF SHIP PRODUCTION.

15. The aim of the shipbuilder is to produce at the lowest possible first cost, subject to a proper provision for wear and tear, an instrument of transportation which will carry a given quantity of goods at a desired speed. It is, therefore, of importance to study two broad factors—economy of material and economy of labor. Both these factors must be considered in conjunction, since in general, saving in weight involves increase of labor, and it is of little use to build a vessel so light that the increased first cost becomes prohibitive commercially. With this restriction in mind, it is best to consider the material side of production independently of the problems relating to labor.

C. ECONOMY IN MATERIAL.

16. Before it is safe to introduce variations in disposition of the material in the structure, it is necessary to have a clear understanding as to the functions of the various members. In short, it would be of advantage to reason out an anatomical analysis of the duties performed by longitudinal, by transverse, and by the various local details which experience shows to be necessary. It is comparatively easy to increase the proportion of the material employed in the longitudinal direction, but this must not be done at the expense of transverse or local strength. Consequently, since each of these three important points have to be correlated, any close study of the structure of a vessel will be of enormous advantage in facilitating future progress.

17. *Distribution of Material.*—It has been rather unfortunate that in past times it has been conventionally agreed that certain parts of the structure are only called upon to meet strains in one direction—that is, the straining forces have been analyzed in respect of either the longitudinal, transverse, or local senses. In general, however, some parts may be called upon to bear stresses arising from both longitudinal and transverse straining actions as well as local conditions. It is largely a matter of conjecture what provision is necessary to bear the combined results; it is not in general true to infer that the material must be sufficient on the one hand to withstand either the maximum strain in any sense, or, on the other hand, to assume that the arithmetical sum of the strains must be met. In considering redistribution of material, therefore, it will be desirable, as far as practicable, to depart from this present convention and to estimate the interaction of adjoining parts of the structure under combined stress. Any attempt to reduce weight must generally have as its basis an increase in longitudinal material. For since the maximum strains on a vessel occur in the longitudinal direction, the more material is massed in that direction, the more is the stress on the material brought into line with that experienced in other directions. In the same manner, saving of weight is effected by reducing the transverse allocation of material to the minimum necessary for that purpose. The manner in which transverse straining action is met is still very obscure; and although some methods of calculation are available, yet these methods are from the very nature of things complex, and so difficult of application that their common use is still far distant.

A research into the possibilities of maximum amount of material for longitudinal distribution and a minimum amount for transverse requirements is eminently desirable. But coupled herewith must be considered the alterations in works processes which are likely to be required. Local strains are still more difficult to evaluate, and can only generally be met by a close study of experience at sea. Merchant vessels are particularly prone to sea damage at the forward end, both in the side plating and in the double bottom. The heavy and unusual duty performed by vessels in war time has accentuated the difficulties ordinarily experienced. Again, although the fibre stress per unit area which material will stand is ordinarily known, or in a ship rather comparatively determinable, yet, under compression, failure may and commonly does occur owing to insufficient local support. There is therefore to be sought a relation for spacing supporting members in terms of the thickness of material, such as a deck which has to be supported against compression. This discussion on local failure brings up the question of secondary bracing. Certain girders and stringers require brackets in order to prevent collapse from oblique loading; it is not an easy matter for any form of calculation, but a close study of actual experience should produce rules for general guidance.

18. *Construction of Double Bottom.*—Even the most enlightened naval architects appear to have only hazy ideas concerning the structural work performed by the complicated double bottom which is now a common feature in merchant ships. The more general practice is to dispose the internal framing in the transverse direction, retaining a very small amount of longitudinal material mainly for local support. These longitudinal intercostal members also fulfil some function as secondary bracing, but the nature of the work performed is very obscure. It is, of course, true that facility of erection has favored transverse framing; but here again, if economy of weight is required, search must be made for a distribution which is more in the longitudinal sense than the present practice. Some well-known efforts have already been made towards this aim, but the final solution has yet to be sought. It certainly seems possible to make some comparative calculations on the strength of the double bottom as a whole when

regarded as a strut under compression. The labor involved is, however, immense, and so far no one has attempted a solution. The double bottom of a merchant vessel suffers much from inaccessibility, and any development which would mitigate this important disadvantage would be welcome so long as the structure were able to perform its work efficiently.

19. *Stiffness of Structure.*—Although stiffness and deflection are closely studied in land structures, yet as far as ships are concerned insufficient attention has been paid to this important matter. It is certainly true that the Registration Societies provide some safeguard against undue deflection, which limitation is expressed very generally as a proportion between length and depth of structure. It is extremely desirable for economy of material to extend our knowledge of this branch of study in order to obtain the best disposition of material. Something can certainly be done by experiments on the breakage or deflection of vessels when loaded, in comparison with the results of calculation. Such experiments were made in the early days of shipbuilding, but further work on more modern forms of structure is most desirable. Attention might also be called to the necessity of giving more consideration to the question of stiffness of transverse and longitudinal framing. It is difficult even to give an idea as to the form such an investigation would take, as the calculations required are much more involved than those for transverse strength already mentioned.

20. *Efficiency of Connections.*—This question is of the highest importance, since it is of little use to provide structural material and then court failure in the method of attachment. The experience of many years certainly indicates that, generally speaking, the present systems of riveted connections perform their work well in regard to main structural stresses, and in cases of local stresses the alterations dictated by experience have fairly well met the needs. The growth in size of vessels has resulted in increased size of rivets with a consequent need for the greater use of power tools. It has, however, become desirable to ascertain whether, under modern conditions, it would not be possible to make alterations in methods of connection and reduction in sizes of rivets without sacrifice of efficiency. There is not sufficient information at present available to indicate precise directions in which investigation might possibly proceed. It is to be hoped, however, that this defect of knowledge will be remedied in the not too distant future.

D. ECONOMY OF LABOR.

21. Although post-graduate research scholarships in naval architecture have been in operation for some time, and although the attached conditions clearly contemplate that research students should investigate the development of the shipbuilding industry at home and abroad, yet so far this important purpose has not been realized. The increase in the remuneration of labor, and the paramount necessity of the country in post-war times to maintain its previous industrial activities, makes it necessary closely to investigate economy of labor in shipbuilding operations. Study of labor processes has already been somewhat widely undertaken in some branches of the engineering industry, but this study has been largely confined to the mechanical side, and it would appear that insufficient attention has been given hitherto to the question of shipbuilding.

The question appears to be dominated by two main considerations:—

(*a*) Increased output of labor, and

(*b*) Disposition of material to ensure a minimum amount of labor.

Increased output of labor involves the provision and proper utilization of labor-saving devices, but here it must be remembered that saving is not effected unless the time factor for an operation is properly related to the time factors of the other processes. For example, it would be useless to speed up the preparation of plates unless the output of the supporting framing were adjusted equally. Consequently, although one particular class of employee would be producing at a higher rate, the periods of delay in other processes would reduce and prevent any ultimate gain.

The need of the study of the problem as a whole, and not for particular items, is at once evident, for otherwise labor must raise objections to an introduction which would not ensure continuity of employment. On the other hand, the workman must recognize that he is unable to increase his earnings without a corresponding co-operative effort on the part of the employer to regulate the other branches of the establishment. Increased output is therefore only possible by the joint effort of employer and workman, and by a joint increase of remuneration for both parties concerned.

It has often been mentioned that low first costs involve savings of both material and labor. On the other hand, reduction of weight often involves a redistribution of material, and it may happen a consequent increase in labor. A close study of the labor charges for each structural detail is necessary in order to obtain a proper balance, and it will often happen that the disposition of material will be determined rather by labor requirements than by structural necessity, although at the same time the strength must be properly maintained. It is certainly true that individuals have given careful attention to this point in the severe stress of pre-war competition, but this very fact has prevented that inter-change of ideas which would be of the greatest value to the industry as a whole. It may be of interest to give some detailed views of the directions in which the study of labor problems might possibly be undertaken.

22. *Work Preparatory to Construction.*—There appears to be room for improvement in drawing-office and mould-loft practices, which ought to bear a close relation to the labor processes required for actual construction. Study of form and disposition of plating would tend to reduce scrap and to avoid much shaping of plates. It would be a great advantage if plates could be made rectangular in shape for a good portion of the length and the material then be ready for use as delivered from the steel works. It is considered that even towards the ends it is possible to introduce more parallel plating than is commonly done. Further, the use of templates should be reduced to narrow limits either when provided from the mould loft or when obtained from the ship during erection.

23. *Fashioning of Material.*—The increased use of parallel plates already mentioned will avoid shearing if the steel works shape the plate as nearly as possible to the dimensions. The trimming of butts and edges might conveniently be studied with a view to save labor. Recent developments in the use of the multiple punch for ship work have shown that this system can be well adapted, and that to a large extent for shell and deck plating. It appears that a careful study of the plating model will enable this system to be conveniently applied well towards the ends of the vessel. The form might also be conveniently adjusted with the same point in view. Smiths' work, which is both costly and difficult, might be increasingly avoided by arranging for repetition work as much as possible, and fashioning these parts in numbers by hydraulic presses. The avoidance of templating at the ship must lead to increased output, and here again arrangements for repetition work would be of great advantage.

24. *Erection, including Connections.*—This question involves careful consideration of berth appliances, a subject for close study in itself, and one which has frequently been discussed before this Institution. The sizes and weights of the pieces to be handled are of importance, and such pieces should be as large as conveniently possible to reduce labor of connection. The structural details should be so arranged that the parts are conveniently attached, and can be temporarily placed in position without much adjustment and without distorting appreciably under their own weight.

The use of power riveting tools can, in the opinion of most builders, be largely extended, more particularly perhaps in the direction of pneumatic appliances. In this case, however, great care is required in the periodical inspection of the tools and of the plant in order to obtain a sufficient and constant supply of power at the ship, and in order to insure that the riveting machines are giving out the proper power in relation to the consumption of air. It appears necessary to devise certain simple tests and gauges which shall indicate these requirements. Power riveting has become of increasing importance with the modern increase of size of merchant vessels and the consequent increased thicknesses of material. The extension of hydraulic riveting is therefore of some importance, but hydraulic power is not so conveniently applied, and is expensive in operation.

There are also indications of a future possibility that some forms of electric welding may be adapted for structural work. In such case it will be necessary to devise works processes suitable to such forms of connection which must involve departures from existing methods of erection.

25. *Completion of Vessels.*—In the later stages of construction it is necessary to devote considerable attention to the fitting of the equipment, the navigation instruments, and the multitudinous items necessary to the proper working of the vessel. It would appear to be to the advantage of the whole industry to take steps to secure bulk manufacture of these numerous small details by setting up standard forms. It also appears desirable that steering gears and engines should conform to certain standard specifications, and that boats and davits should be of interchangeable patterns. The study of cargo-handling appliances, winches, blocks and so forth would result in saving of cost and increase of output. In fact, the question of equipment would repay careful investigation by the industry as a whole with a view to the adoption of bulk production.

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26. It has not been possible to give more than the merest indications of the directions which investigation should take in the wide field of naval architecture. It appears that there is much room for study—very much more room than was expected when this paper was begun. It will be admitted that the aim of this country should be to re-establish her maritime sea power at the earliest possible moment. It is therefore beyond doubt, in view of the stringent economic conditions that must prevail when peace is declared, that there is a striking and immediate necessity to study the factors which will improve the production of vessels, or, in other words, to encourage a widespread interest in research in naval architecture. It is to be hoped that in the national interest the whole of the shipping community will work together, and not expect research to be undertaken by any one section of the industry.

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